Attentional ERPs and Attitude to Risk

James Kirkcaldie

Department of Psychology
University of Tasmania

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I declare that this report is my own original work, and that contributions of others have been duly acknowledged.

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Elements within Extroversion: A Physiological Approach

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Abstract

The introversion-extraversion spectrum has remained a major focus for research into the biological basis of personality. Most recent work suggests that introverts exhibit greater phasic arousal to stimuli of moderate intensity, whereas extraverts display larger responses to more intense stimuli (Stelmack, 1990). For this reason, extraverts are often considered more likely to be drawn to high-arousal activities such as gambling (Hatano & Inagaki, 1977). However, this logical assumption has failed to find support in a number of studies (Ansari & Ahmad, 1977; Barnes & Sharda, 1987), which have shown no correlation between extraversion and gambling. Instead, measures of a participant's risk-taking tendencies (an independent element within extraversion) have proven to be the best indicator of their attraction to gambling (Ansari & Ahmad, 1977). Given this, value appears to lie in future research investigating whether physiological differences exist between extravert groupings and, by extension, how this may relate to activities such as gambling.

Many psychologists consider differences in personality to be a reflection of unique biological underpinnings. However, a clear understanding of the physiological processes that may be involved has remained elusive, despite having been explored since the late 1930s (Cahill & Polich, 1992).

The introversion-extraversion personality dimension has provided a major focus for such physiological research. Consequently, this spectrum is thought to have acquired a better theoretical substructure and identified more links with physiology than most (Eysenck, 1981).

One of the most widely recognised biological theories explaining the existence of personality is Eysenck's (1967) 'arousal theory'. This theory focuses on the introversion-extraversion personality dimension and the region of the brain stem Eysenck considered responsible for this continuum: the ascending reticular activating system (ARAS). However, with the development of this theoretical framework came debate as to what this personality construct actually represented and its overall validity. This was most evident with the concept of extraversion – seen as 'sociability' by American researchers, whereas European researchers associated it with 'impulsiveness' (Carrigan, 1960). Eysenck and Eysenck (1963) acknowledged this by recognising sociability and impulsiveness as discrete components within extraversion. However, this distinction was then complicated by a further subdivision of 'impulsiveness' (in its broad sense) into four sub-factors: impulsiveness (specific), risk-taking, non-planning, and liveliness (Eysenck & Eysenck, 1977).

Whether these sub-traits of extraversion have some sort of physiological basis remains unclear and provides the focus for this review. Accordingly, this paper will consider the findings of relevant electrodermal and electroencephalographic (EEG) research, before attempting to unite this with more behaviourally oriented data relating to the arousal-oriented activity of gambling. It is hoped that by doing so, more specific, potentially physiologically significant personality characteristics associated with gambling may be identified for future investigation.

Introversion and Extraversion

Evidence suggests that the foundations of the introversion-extraversion personality dimension originate as far back as the 17th century, with references from this period identifying an extravert-like quality where the mind is turned outward of one's thoughts toward objects (Zumbo & Taylor, 1993). This is reflected in the terminology, with "extraversion" combining "extra" meaning "outward", and "vertere" which translates as 'to turn", whereas "introversion" has the prefix "intro" meaning "inward" (Zumbo & Taylor, 1993).

In accordance with the literal definition, introverts are widely recognised as those individuals who centre upon an inner world of subjectivity and mental activity, whereas those referred to as extraverts tend to orient themselves towards, and interact more, with the external environment (Eysenck, 1967). Such a division in personality was thought to indirectly reflect differences in preference for, and reaction to, stimuli. In neurophysiological terms, introverts were thought to exhibit greater chronic arousal as compared to extraverts within the ascending reticular activating system (ARAS) of the brain stem (Eysenck, 1967) – the system thought to be responsible for arousing and inhibiting both cortical and autonomic activity (Stelmack, 1990).

The ARAS involves a lattice-work of short nerve cells utilised by the main sensory pathways and is recognised as being part of the specific thalamic projection system (Stelmack, 1981). The ascending sensory pathways excite cells in the ARAS via collaterals, which then transfer this excitation to an array of sites in the cerebral cortex and thalamic projection system (Stelmack, 1981). Eysenck (1967) proposed in his 'arousal theory' that this transfer of excitation was ultimately greater for introverts, as he believed their baseline levels of arousal were higher than those for extraverts and that this made them more sensitive to the processing of sensory stimuli. This appeared to be supported by observations suggesting introverted individuals were more responsive to environmental conditioning and able to attend more easily to new information than extraverts (Stelmack, 1981).

While Eysenck's (1967) arousal theory provides a framework to explain the psychophysiology of the introversion-extraversion personality dimension, the question remains as to whether subsequent attempts to define this personality dimension empirically are of value. Zumbo and Taylor (1993) suggest that estimating the validity of empirical measures of the extraversion-introversion personality dimension is often difficult because it is generally intertwined with construction and verification of scientific theories. Accordingly, validity should reflect whether the criterion scales correlate and measure with their conception of extraversion. This touches upon Campbell and Reynolds' (1984) warning, which relates to the fact that the actual labels attached to concepts and scales should not provide the focus of investigation, given that semantic similarity bears no relationship to – and cannot substitute for – empirical similarity.

In response to this, Zumbo and Taylor (1993) combined existing extravert-introvert subscales from the Myers-Briggs Type Indicator (MBTI), the Eysenck Personality Questionnaire (EPQ), and the Howarth Personality Questionnaire (HPQ) to assess the consistency of extraversion's representation in these tests. The results suggested that extraversion as measured by these three scales was not completely unitary, although inter-factor correlations did exist in varying degrees. Upon further inspection, support was found for Campbell and Reynolds' (1984) notion that semantic similarity does not equate to empirical similarity. In so doing, Zumbo and Taylor recognised Eysenck and Eysenck's (1963) earlier work that ensured the EPI's extraversion measured elements of sociability and impulsivity, which in turn were incorporated in the development of Eysenck's (1967) arousal theory.

Autonomic and Electrocortical Studies of Introversion and Extraversion

Introverts-Extraverts and Skin Conductance Response

In accordance with Eysenck's (1967) arousal theory, many of the psychophysiological studies examining the introversion-extraversion personality dimension have revealed enhanced autonomic reactions and electrocortical activity for introverts in those areas modulated by the ARAS (Stelmack, 1990). However, while the findings of many studies have supported this hypothesis, some have not – a fact which may be attributed to inappropriate methods, the nature of the underlying determinants being examined (Stelmack, 1990), or different personality scales used to group participants (Zumbo & Taylor, 1993). Irrespective of what these differences reflect, Stelmack (1990) suggests that the findings both for and against the arousal hypothesis actually serve to outline the exact conditions required for reliable differences between introverts and extraverts to be observed.

In constructing this hypothesis, Stelmack (1990) considered a number of studies which failed to identify any significant skin conductance response (SCR) differences between introverts and extraverts when using low-intensity auditory stimulation of 60 dB or less (Coles, Gale, & Kline, 1971; Hastrup, 1979; Mangan & O'Gorman, 1969; Sadler, Mefferd, & Houck, 1971). This was contrasted by findings associated with the presentation of visual and auditory stimuli of moderate-intensity (75-90 dB), which showed introverts elicited larger SCR amplitudes through greater initial response amplitudes, slower habituation rates, more frequent number of responses, or greater responses to test stimuli following a repetitive habituation series (Crider & Lunn, 1971; Gange, Geen, & Harkins, 1979; Mangan & O'Gorman, 1969; Wigglesworth & Smith, 1976). However, when experimental conditions involved higher intensity stimuli, the SCR effects were reversed, with extravert responses greater in amplitude (Wigglesworth & Smith, 1976).

Eysenck's (1967) arousal theory accommodates this pattern of findings by assuming introverts have a 'weaker' nervous system. This more stimulus-sensitive nervous system is thought to provide the basis for introverts' tendency to elicit larger SCRs in response to more moderate stimuli, while their observed smaller SCR reactions to stimuli of a high-intensity are considered to reflect the activation of protective, inhibitory processes (Stelmack, 1990).

Electrocortical Activity

The trends evident in the electrodermal findings have also been identified within those studies examining cortical activity. Savage (1964) was one of the first to record introvert-extravert differences in cortical arousal by comparing their respective EEG (Electroencephalographic) activity when resting. When awake, high levels of arousal are characterised by low amplitude, high frequency alpha activity (EEG ranging between 8-13 Hz). Savage hypothesised, and his results suggested, that this type of EEG pattern was typical of introvert brain activity at rest, a notion Eysenck (1967) incorporated in the development of his arousal theory.

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However, Stelmack (1981) suggests that subsequent attempts to investigate this theory and clarify any physiological basis for the introvert-extravert personality dimension initially only served to confuse the issue with inconsistent and contradictory results. The EEG findings of Gale, Coles, and Blaydon (1969), Morris and Gale (1974), and Frigon (1976) all associated high levels of cortical arousal with introversion, whereas Fenton and Scotton's (1967), Gale, Coles, Kline, and Penfold's (1971), Winter, Broadhurst, and Glass' (1972), and Becker-Carus' (1971) results failed to provide any evidence to support such an association. To further complicate the issue, studies by Broadhurst and Glass (1969) and Gale, Harpham, and Lucas (1972) showed support for the contrary hypothesis, with extraverts displaying greater inherent levels of arousal.

Stelmack (1981) believes the inconsistencies shown in the results of these EEG studies of introversion-extraversion may be attributable to differences in recording, scoring (some by hand), selection of participants, and general procedure. More specifically, a lack of uniformity between studies is evident in aspects such as the placement of electrodes, the methods for reducing EEG data, as well as the indices defining alpha activity. In addition, Stelmack (1990) suggests that the irregularities evident in those electrocortical studies examining more tonic levels of arousal in awake participants may be subject to contamination in the form of stimulus effects embedded in the waveforms.

Other possible sources of variation may include the participants' required level of consciousness (ranging from semi-somnolent states to concentrating on arithmetic problems) and sex ratio, although this was not relevant to those studies with evenly mixed samples (Gale et al., 1969; Becker-Carus, 1971; Morris & Gale, 1974). Participant age differences have also been shown to influence EEG activity (Friedman, Boltri, Vaughan, & Erlenmeyer-Kimling, 1985).

One factor that appears unlikely to have played a role in the variations shown in the findings of extraversion-introversion EEG studies is time of day. Gale, Harpham, and Lucas (1972) showed this variable had little impact upon introvert or extravert EEG activity, with recordings at 7am, 11am, 3pm, and 8pm, failing to differ significantly within individuals.

Refining Eysenck's (1967) Arousal Theory

While numerous discrepancies have been identified in the results of the reported SCR and EEG studies into the introvert-extravert personality dimension, one observation appears to remain constant: no introvert-extravert differences have been found while the participants are at rest. This encouraged Stelmack (1990) to propose a possible physiological basis for the introvert-extravert personality dimension relating to the idea that introverts appear to exhibit a greater transient reaction to sensory stimulation than extraverts. This effectively refines Eysenck's (1967) arousal hypothesis, which did not consider the distinction between basal and transient types of arousal and assumed there was a difference between introvert-extravert baseline levels of arousal to begin with. Stelmack and Geen (1992) provide further support for this notion by again highlighting the fact that neither electrodermal nor EEG analyses have shown consistent introvert-extravert differences in basal arousal, whereas electrodermal and event-related potential (ERP) studies using particular stimuli show introverts consistently react more.

Campbell, Baribeau-Braun, and Braun (1981) also challenge Eysenck's (1967) arousal theory by suggesting that such introvert attributes are unlikely to originate within peripheral or brainstem areas, but appear specific to cortical regions. They interpret the arousal response of introverts and extraverts, like Stelmack (1990), as a transitory state reflecting the individual's perception of the stimulus.

Event-Related Potentials

Given Stelmack's (1990) and Campbell et al.'s (1981) concerns about Eysenck's (1967) arousal theory, future research would appear best directed towards focusing on more cortical aspects. However, the inherent problems with studies comparing introvert-extravert electrocortical activity in terms of overall EEG suggest event-related potentials (or evoked potentials) are a far more suitable method with which to examine electrocortical activity and the introversion-extraversion personality dimension.

ERPs consist of a series of identifiable EEG wave components thought to index the physical and cognitive properties associated with a particular stimulus (Donchin, Ritter, & McCallum, 1978). Such a measurement appears most suited to monitoring the transient physiological reactions Stelmack (1990) identified as being definitive for the introversion-extraversion personality dimension. Recorded from the participant's scalp, samples of mass of EEG activity are time-locked with the presentation of a particular stimulus, allowing stimulus-specific ERP waves to be compiled using a signal-averaging technique (Duncan-Johnson & Donchin, 1982).

Exogenous ERP Components

Components of the ERP are thought to reflect the brain's recognition of the physical properties of the evoking stimulus, the cognitive processes generated by the presenting stimulus, or a combination of the two (Hillyard & Picton, 1979). By strict definition, exogenous ERP components are those elicited within the first 40ms or so after stimulus onset (Hillyard & Picton, 1979). This type of component has been shown to depend upon the physical properties of the stimulus and occurs regardless the person's state of alertness (Hillyard & Picton, 1979). However, if components within the ERP wave are divided dichotomously into exogenous and endogenous categories (the latter reflecting cognitive processes), the exogenous part of the ERP waveform may be expanded to incorporate components elicited up to approximately 250 ms after stimulus onset (McDonough, Warren, & Don, 1992).

Introvert-Extravert Differences in Exogenous ERP Components

Introvert-extravert differences in exogenous components were identified by Stelmack, Achorn, and Michaud (1977), who examined the auditory evoked responses (AERs) of introvert-extravert groupings in response to low (500 Hz) frequency tones at 55 and 80 dB levels of intensity. Stelmack et al. found introverts elicited larger N1-P2 amplitudes than extraverts for this combination of tones, implying that greater attention was paid to these stimuli (Näätänen, 1975). This was in accordance with Stelmack et al.'s expectations, as previous research had shown that introverts have greater absolute auditory sensitivity when tested in a low frequency (500 Hz) signal detection task (Stelmack & Campbell,

1974) and perform better in tasks that required attention or vigilance (Harkins & Geen, 1975). Stelmack et al. interpreted this as evidence that introverts generated higher levels of cortical excitation and lower levels of inhibitory potential compared to extraverts for stimuli of low and moderate intensity, partially supporting Eysenck's (1967) theory.

Introvert-extravert ERPs to Varying Stimuli

While it can be argued that ERP recordings are well suited to investigating phasic differences within this personality dimension, one measurement in particular appears very suited to future research. Given Stelmack et al.'s (1977) findings (highlighting introvert-extravert differences in the exogenous N1 and P2 components) and those reported by Bruneau, Roux, Perse, and Lelord (1984), mismatch negativity (MMN) may well be a sensitive ERP measure of introvert-extravert differences.

Bruneau et al. (1984) found that when auditory stimuli were varied within a series (either in terms of intensity or frequency) auditory evoked response (AER) amplitudes (measuring P1 to N1 and N1 to P2) showed introvert-extravert differences. Extraverts were more 'reducing' than introverts, particularly at Fz, indicating that they judge the magnitude of the incoming stimulus as markedly reduced. This fits with Eysenck's (1967) 'arousal theory' and its subsequent refinements, as well as indirectly confirming the potential suitability of MMN as a measure, given that the study focused on an exogenous area of the ERP waveform and because Bruneau et al. suggested that "... cortical reducing could be related to a regulatory mechanism involving the frontal cortex..." (pp. 549).

Mismatch Negativity

MMN is a negative exogenous component of the auditory ERP which reflects unattended, but processed, changes in auditory stimuli. This component may be found approximately 150-250 ms after an unexpected change in sound is detected by the brain following a sequence of previously homogeneous stimuli (Näätänen, 1982): a situation which has been shown to elicit different introvert-extravert reactions (Bruneau et al., 1984).

Variations in MMN's latency, duration, and amplitude reflect the degree of difference between the average waveform elicited for the habituated, uniform tones and the waveform produced in response to the deviant stimulus. MMN may be generated as a result of stimuli deviating from those previously presented in terms of pitch (Näätänen, 1986; Nordby, Roth, & Pfefferbaum, 1988), intensity or duration (Näätänen, 1982), interstimulus-interval (Ford & Hillyard, 1981), or by way of more elaborate means, such as infrequent order reversals of tone intensities in discretely presented tone pairs (Schroger, Tervaniemi, Wolf, & Näätänen, 1996). These types of deviations may also interact with each other, with Schroger's (1996) work showing the MMN elicited by a change in stimulus intensity was significantly modulated by both intensity and interstimulus interval, whereas frequency-evoked MMN was not effected by these variables.

Characteristics of MMN and the Effect of Attention.

MMN reflects the ability to store information about antecedent stimuli and compare it with incoming stimuli (Näätänen, 1982). This process is considered to be unique to auditory stimuli, with deviations in other modalities failing to elicit MMNs (Nyman, Alho, Laurinen, & Paavilainen, 1990). Accordingly, electro- and magneto-encephalographic dipole mapping studies have indicated that the mechanism associated with MMN originates from the supratemporal auditory cortex of the brain (Javitt, Steinschneider, Schroeder, Vaughan, & Arezzo, 1994), with related information thought to form a 'trace' through this area.

The MMN process is thought to be preattentive and automatic, as it is unaffected by attention or stimuli significance (Näätänen, Simpson, & Loveless, 1982). Paavilainen, Tiitinen, Alho, and Näätänen (1993) confirmed this with their study which showed slight deviations in frequency produced consistent MMNs, regardless of whether the participant was attending or not – suggesting that at least auditory frequency is fully analysed in the absence of attention. This may have indirectly contributed to the good test-retest stability observed by Pekkonen and Rinne (1995) when examining MMN in response to deviations in frequency and duration, prompting them to suggest that it can be used at both a group and individual level.

However Woldorff, Hackley, and Hillyard (1991) found that the MMN produced in response to small deviations in tone intensity attenuated when participants were not attending (compared to when the tones were attended); implying that MMN is not an entirely preattentive process. Näätänen (1991) challenged this statement by suggesting that the attenuation Woldorff et al. observed was most likely a reflection of attention's effect on the MMN mechanism itself (rather than the antecedent sensory-analysis and sensory-storing functions as they inferred).

Näätänen's (1991) explanation of Woldorff et al.'s (1991) findings follows on from observations made by Näätänen, Simpson, and Loveless (1982) relating to what is referred as the N2b component. They argued that this more central component (in terms of scalp distribution), followed and partially overlapped the more frontally located MMN component when the participant attended in their experiment, giving the impression that attention had a dramatic effect on MMN. Näätänen, Paavilainen, Tiitinen, Jiang, and Alho (1993) echo these findings, with results showing that the N2b component was only elicited in response to deviant inputs which were attended.

Näätänen (1991) further explored the possibility that attention may influence the brain's reaction to deviations in tone, by manipulating the frequency and intensity of the stimuli presented. By reversing the MMN polarity at the mastoids (with a nose reference), Näätänen was able to get a more accurate assessment of attention's role, as this meant that the MMN components were viewed without any overlap of the N2b component. The results suggested that the MMN generated by changes in frequency was not altered by attention, although the MMN originating from unexpected changes in intensity did show attentional effects, albeit a lot more modest than those reported by Woldorff et al. (1991). However, Näätänen still concluded that MMN (and the sensory analysis, memory development, and comparisons associated with it) can occur in the absence of attentional modulation (evident in those responses to deviations in frequency). He concludes that there may be separate mechanisms for generating frequency and intensity deviant based MMNs, a theory explored further in Paavilainen, Tiitinen, Alho, and Näätänen's (1993) paper.

MMN as a Measure of the Introvert-extravert Personality Dimension.

Having recognised attention's potential to influence the N2 component and subsequent measures of MMN, it is interesting to note that concerns of a similar nature were raised in Stelmack et al.'s (1977) ERP study. Stelmack et al. queried whether the enhanced auditory-evoked response elicited by introverts to low frequency stimuli of both low and moderate intensity could have been affected by introverts paying more attention to the instructions given or to the tones themselves. This was subsequently investigated in Stelmack and Achorn's (1985) paper in which it was reported that participants were asked to either attend or ignore a series of low frequency tones. Their findings echoed those of Stelmack et al.'s previous experiment, with introverts eliciting larger amplitude waves in the 100 to 200 ms period following stimulation, but failed to establish clear differences between attended and unattended conditions. This led Stelmack and Achorn to conclude that the previously identified introvert-extravert differences were not due to attentional mechanisms and appears to further reinforce MMN's suitability as a unit of measurement.

The N2 Component.

While the N2 component is believed to relate predominantly to the exogenous qualities of the stimuli (frequency or intensity for example), many believe it encompasses some of the stimuli's subjective value (Bartussek, Diedrich, Naumann, & Collett, 1993). In this context, the N2 may be seen as part of the transitional part of the ERP wave, where both exogenous and endogenous aspects are combined (Hillyard & Picton, 1979). This section of the ERP wave has remained a focal point for research into personality and gambling, as have the later (endogenous) ERP components.

Endogenous ERP Components

The later parts of the ERP waveform are considered to represent a person's internal cognitive operations and are referred to as endogenous. The P3, the contingent negative variation (CNV), and the readiness potential (RP) are but a few examples of these components. Their internal origin is evidenced by studies showing that the same physical stimulus may be presented to a participant only to induce different later, endogenous, ERP components (Donchin et al., 1978). Moreover, these components may be triggered by the absence of an expected stimulus and therefore must be endogenous. The amplitude, latency, and scalp distribution of these potentials, however, may be influenced by external stimuli, with variance thought to be accounted for by differences in the participant's task (Donchin et al., 1978).

The P3 Component.

Of all the endogenous components, the P3 has figured most prominently in recent ERP research, generating great interest in its possible functional significance. Studies have shown that P3 latency depends on the time needed to identify the stimulus, evaluate its relevance to the task, and assess its likelihood (Squires, Donchin, & Squires, 1977). These processes take longer with visual stimuli, rather than auditory cues (Squires, Donchin, &

Squires, 1977), and are thought to be independent of the participant's eventual reaction time to the stimulus (Duncan-Johnson, 1981; Duncan-Johnson & Donchin, 1982). The amplitude of the P3, on the other hand, is considered to relate directly to the probability of the stimulus, with less probable events resulting in larger amplitudes (Kutas, McCarthy, & Donchin, 1977; Squires, Donchin, & Squires, 1977).

ERP Components as an Index of Gambling

Given the fact that ERP wave components reflect various aspects of information processing (both physical and cognitive), it is feasible that observed differences between people regarding these components could relate to their personality types. Such inherent physiological differences would naturally influence the perception of a person's environment (Cahill & Polich, 1992); a hypothesis which Bartussek et al. (1993) adopted in their study looking at introvert/extravert brain activity in pseudo-gambling situations (where tones indicated a win or a loss).

Bartussek et al. (1993) found that the amplitude and latency of the P2, N2, and P3e (or an early P3 component) they measured, were in accordance with their predicted introvert and extravert reactions. Extraverts elicited their largest P2 amplitude overall for 'winning' tones; a trend which was reversed in the introvert ERP recordings. Bartussek et al. (1993) interpreted the results as showing extraverts react most to a win, encouraging them to gamble, whereas introverts are most affected by a loss, making them less likely to gamble. The largest P2 amplitudes were elicited for the biggest extravert wins or introvert losses (the latter involving comparatively smaller amplitudes).

The ERPs of extraverts were also found to exhibit significantly more positive N2 amplitudes than introverts for high, winning tones, while losses elicited more positive N2 amplitudes in introverts (at the F_Z site; although still smaller than those recorded for the extraverts). Bartussek et al. (1993) considered these N2 results from an emotional perspective, suggesting that the more positive N2 correlated with a greater emotional significance, particularly as the N2 amplitude was most positive for both groups when the largest bets were at stake. Accordingly, it was argued that extraverts are more likely to gamble than introverts.

However, the interpretation of the P3 data was slightly more ambiguous, with the trend shown by the P2 and N2 components continuing only for those introverts and extraverts who scored highly on a scale of neuroticism. Less neurotic extraverts exhibited the same P3 amplitudes regardless of gambling result, whereas introverted participants (with low levels of neuroticism) had larger P3 amplitudes for wins. This left Bartussek et al. (1993) to take refuge in the fact that the differences between the more neurotic extraverts and introverts were more pronounced than those involving the less neurotic participants.

Barnes and Sharda's (1987) study may partly support Bartussek et al.'s (1993) P3 findings, as they illustrated that compulsive gamblers were significantly more neurotic than non-gamblers, indicating that the P3 recordings for the highly neurotic extraverts/introverts are perhaps more important in a gambling context.

Gambling

With a significant proportion of psychophysiological research indicating that introverts are more sensitive to stimuli of varying modalities than extraverts, a logical conclusion would be to suggest that extraverts would be more attracted to arousal-oriented activities such as gambling. This is largely based on the view that physiological reaction to arousal (or excitement) is considered critical in determining an individual's attraction to gambling (Anderson & Brown, 1984). This appears to be supported by findings from physiological studies such as Bartussek et al.'s (1993), as well as those from more behaviourally-oriented research such as Hatano and Inagaki's (1977), who found that extraverts were more likely to take greater risks while betting in a gambling situation (significantly more than introverts).

However, despite this empirical support and seemingly sound theoretical basis, the issue remains far from clear cut. Barnes and Sharda's (1987) study on compulsive and non-gamblers failed to find any significant relationship between extraversion and gambling. Instead, the Eysenck Personality Inventory (EPI) showed that non-gamblers actually reported a higher mean level of extraversion (13.25) than the compulsive gamblers (11.50).

Barnes and Sharda's (1987) findings, while unexpected, indirectly highlight a criticism that has previously been levelled at the extraversion-introversion personality dimension. Carrigan (1960) suggested this personality continuum was not unidimensional, with extraversion being seen more as 'sociability' by American researchers, whereas their European counterparts identified extraversion more with 'impulsiveness'. Eysenck and

Eysenck (1963) acknowledged this by recognising sociability and impulsiveness as distinct elements within extraversion. However, the concept of extraversion was then further complicated by the consideration of Twain's (1957) earlier work, which suggested 'impulsiveness' was composed of a number of underlying factors. These observations encouraged Eysenck and Eysenck (1977) to broaden the concept of extraversion by breaking down impulsiveness (in its broad sense) into four sub-factors: impulsiveness (specific), risk-taking, non-planning, and liveliness.

The notion that extraversion encompasses several quite distinct sub-traits has been supported by later work, including that of Sipps and Alexander (1987). Their work examined the responses of 840 university students to the Eysenck Personality Inventory and the Myers-Briggs indicators of extraversion. Using factor-analysis, they identified three different forms of extraversion, the first of which emphasised sociability, the second accenting impulsivity and non-planning, while the third focused on what was referred to as a liveliness, risk-taking, or jocularity component.

The 'risk-taking' factor that Sipps and Alexander (1987) identified within extraversion was also of interest to Ansari and Ahmad (1977) in their previous study. Like Barnes and Sharda (1987), Ansari and Ahmad found no correlation between gamblers and their EPI extraversion scores, or gamblers and a host of other biological and personality factors measured. However, scores relating to 'risk-taking' proved otherwise, with Ansari and Ahmad's findings showing that measures of 'risk-taking' were significantly higher among gamblers than non-gamblers – again suggesting that this trait is quite distinct from the EPI's extraversion.

Allcock and Grace's (1988) research appears to indirectly support Ansari and Ahmad's (1977) reported association between 'risk-taking' and gambling, through a process of elimination. Their research counters any suggestion that Sipps and Alexander's (1987) second identified type of extraversion, impulsivity, may promote any attraction to gambling. In so doing, Allcock and Grace's results showed that pathological gamblers did not significantly differ from the control group in terms of impulsivity or sensation-seeking.

Conclusion

Risk-taking may now be recognised as a trait independent of extraversion and one which appears to be closely linked with arousal-oriented activities like gambling. Given this hypothesis, future research could investigate physiological differences between extraverted risk-takers and non-risk takers. In so doing, risk-taking's independence from extraversion may be reinforced with physiological evidence in addition to Ansari and Ahmad's (1977) more subjective self-report findings.

Event-related potentials (ERPs) appear particularly suited to research of this nature, as they are sensitive to phasic reactions to stimuli, which are demonstrably consistent indicators of introvert/extravert differences (Stelmack, 1990) and those likely to house any differences between extraverted risk-takers and non-risk takers.

Further research should also consider earlier (exogenous) ERP components (involved in the measurement of MMN), as previous work looking at personality and gambling has tended to centre on more endogenous components of the ERP wave. Such work has therefore focused on perceptions of the stimuli's context rather than more basic reactions to the stimuli's physical properties – an aspect which may also contain clues as to why stimuli or stimulating environments (like gambling) are more attractive to some than others.

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Empirical Study

A Physiological Measure of Risk-Taking Relative to Gambling Behaviour.

James Kirkcaldie

Department of Psychology
University of Tasmania

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Eysenck's (1967) 'arousal theory' is recognised as the cornerstone for a large proportion of physiological research into the introvert-extravert personality dimension. Eysenck's theory incorporated the basic notion that introverts have a higher resting level of internal arousal within the brainstem's ascending reticular activating system (ARAS). Given that the ARAS is the network of fibres considered to be responsible for the arousal and inhibition of both cortical and autonomic based responses, it has been suggested that this indirectly determined an individual's preference for and reaction to stimuli (Stelmack, 1990). In accordance with this, Eysenck assumed that introverts were more sensitive to the processing of sensory stimuli and so were more reluctant to interact with stimulating environments.

Many of the psychophysiological studies examining the introversion-extraversion personality dimension have indeed revealed enhanced autonomic reactions and electrocortical activity for introverts in those areas modulated by the ARAS (Stelmack, 1990). However, a number of studies have failed to support this hypothesis – an inconsistency which Stelmack (1990) finds particularly useful in defining the exact conditions required for reliable differences between introverts and extraverts to be observed.

In constructing this hypothesis, Stelmack (1990) considered a number of studies which failed to identify any significant skin conductance response (SCR) differences between introverts and extraverts when using low-intensity auditory stimulation of 60 dB or less (Coles, Gale, & Kline, 1971; Hastrup, 1979; Mangan & O'Gorman, 1969; Sadler, Mefferd, & Houck, 1971). This was contrasted with findings associated with the presentation of visual and auditory stimuli of moderate-intensity (75-90 dB), which showed introverts elicited larger SCR amplitudes through greater initial response amplitudes, slower habituation rates, more frequent number of responses, or greater responses to test stimuli following a repetitive habituation series (Crider & Lunn, 1971; Gange, Geen, & Harkins, 1979; Mangan & O'Gorman, 1969; Wigglesworth & Smith, 1976). However, when experimental conditions involved higher intensity stimuli, the SCR effects were reversed, with extravert responses greater in amplitude (Wigglesworth & Smith, 1976) – a finding thought to reflect the introverts' activation of protective, inhibitory processes (Stelmack, 1990).

The trends evident in the above electrodermal findings have also been identified within those studies examining cortical activity. The electroencephalographic (EEG) findings of Gale, Coles, and Blaydon (1969), Morris and Gale (1974), and Frigon (1976) all associated high levels of cortical arousal with introversion, whereas Fenton and Scotton's (1967), Gale, Coles, Kline, and Penfold's (1971), Winter, Broadhurst, and Glass' (1972), and Becker-Carus' (1971) results failed to provide any evidence to support such an association. To further complicate the issue, studies by Broadhurst and Glass (1969) and Gale, Harpham, and Lucas (1972) showed support for the contrary hypothesis, suggesting extraverts have greater inherent levels of arousal.

While numerous discrepancies have been identified in the results of the reported SCR and EEG studies into the introvert-extravert personality dimension, one observation appears to remain constant; no introvert-extravert differences have been found while the participants are at rest. This encouraged Stelmack (1990) to propose that any physiological difference may relate to a greater transient reaction on behalf of introverts. This effectively refines Eysenck's (1967) arousal hypothesis, which did not consider the distinction between basal and transient types of arousal and assumed there was a difference between introvert-extravert baseline levels of arousal to begin with. Stelmack and Geen (1992) provide further support for this notion, by again highlighting the fact that neither electrodermal nor EEG analyses have shown consistent introvert-extravert differences in basal arousal. Instead, electrodermal and event-related potential (ERP) studies looking at the transient physiological responses of introverts and extraverts to particular stimuli, have proven to be much more consistent in showing larger introvert reactions to stimuli of moderate intensity.

Recorded from the participant's scalp, ERPs are representative brain waveforms averaged from a number of stimulus-specific EEG recordings (Duncan-Johnson & Donchin, 1982). Components of the ERP wave are thought to reflect the brain's recognition of the physical properties of the evoking stimulus (exogenous), the cognitive processes generated by the presenting stimulus (endogenous), or a combination of the two (Hillyard & Picton, 1979). However, if components within the ERP wave are divided dichotomously into exogenous and endogenous categories, the exogenous part of the ERP waveform is considered to incorporate those components elicited up to approximately 250 ms after stimulus onset (McDonough, Warren, & Don, 1992).

Auditory tones are frequently used when looking at exogenous ERP wave components, as they are easily manipulated and controlled. Stelmack, Achorn, and Michaud (1977) employed this type of stimulus presentation in examining the auditory evoked responses (AERs) of introvert-extravert groupings in response to low (500 Hz) frequency tones at 55 and 80 dB levels of intensity. Stelmack et al. found introverts exhibited larger N1-P2 amplitudes than extraverts for this combination of tones, indicating greater attention was paid to this auditory stimulation (Näätänen, 1975). This was in accordance with Stelmack et al.'s expectations, as previous research had shown that introverts have greater absolute auditory sensitivity when tested in a low frequency (500 Hz) signal detection task (Stelmack & Campbell, 1974) and perform better in tasks that required attention or vigilance (Harkins & Geen, 1975). Stelmack et al. interpreted this as evidence that introverts generated higher levels of cortical excitation and lower levels of inhibitory potential compared to extraverts for stimuli of low and moderate intensity – partially supporting Eysenck's (1967) theory.

While these findings are based on ERP data which is more sensitive to the phasic differences within this personality dimension, there appears to be an even more appropriate ERP-based measurement that has yet to be utilised: mismatch negativity (MMN). This assumption stems largely from Bruneau, Roux, Perse, and Lelord's (1984) study of introvert-extravert differences in response to varying auditory stimuli presented through external speakers. Bruneau et al. found that when auditory stimuli were varied within a series (either in terms of intensity or frequency) auditory evoked response (AER) amplitudes (measuring P1 to N1 and N1 to P2) showed extraverts were more 'reducing' than introverts. This was particularly evident at Fz and indicates that the extraverts perceived the magnitude of the incoming stimulus as markedly reduced – fitting with Eysenck's (1967) 'arousal theory' and its subsequent refinements. These findings, along with Stelmack, Achorn, and Michaud's (1977) reported introvert-extravert differences within the N2 component, indirectly confirm the potential suitability of MMN as an appropriate measure of introvert-extravert phasic differences. More specifically, MMN appears suited given Bruneau et al.'s focus on exogenous components of the ERP waveform, the presentation of unexpected variations in the auditory stimuli to the participants, and the fact that the introvert-extravert differences were most pronounced in the frontal regions of the brain.

MMN is a negative exogenous component of the auditory ERP that reflects unattended, but processed, changes in auditory stimuli. This component is maximal in the frontal regions and is evident approximately 150-250 ms after an unexpected change in sound is detected by the brain following a sequence of previously homogeneous stimuli (Näätänen, 1982). MMN reflects the ability to store information about antecedent stimuli and compare it with information received about subsequent stimuli (Näätänen, Sams, & Alho, 1986). This process is considered to be unique to auditory stimuli, with deviations in other stimuli modalities generally failing to elicit MMNs (Nyman, Alho, Laurinen, & Paavilainen, 1990). Accordingly, electro- and magneto-encephalographic dipole mapping studies have indicated that the mechanism associated with MMN forms a 'trace' through the supratemporal auditory cortex of the brain (Javitt, Steinschneider, Schroeder, Vaughan, & Arezzo, 1994).

Variations in MMN latency, duration, and amplitude reflect the degree of difference between the average waveform elicited for the habituated, uniform tones and the waveform produced in response to the deviant stimulus. MMN may be generated as a result of stimuli deviating from those previously presented in terms of pitch (Näätänen, 1986; Nordby, Roth, & Pfefferbaum, 1988), intensity or duration (Näätänen, 1982), inter-stimulus interval (Ford & Hillyard, 1981), or by way of more elaborate means, such as infrequent order reversals of tone intensities in discretely presented tone pairs (Schroger, Tervaniemi, Wolf, & Näätänen, 1996).

The MMN process is thought to be preattentive and automatic, taking place without conscious awareness of stimulus deviance (Näätänen, Simpson, & Loveless, 1982) and may be elicited in response to small deviations in frequency (Paavilainen, Tiitinen, Alho, & Näätänen, 1993). However, Woldorff, Hackley, and Hillyard (1991) found that the MMN produced in response to small deviations in tone intensity attenuated when participants were not attending (compared to attended tones); implying that MMN is not an entirely preattentive process. Näätänen (1991) countered this statement by suggesting that the attenuation Woldorff et al. observed was most likely a reflection of attention's effect on the MMN mechanism itself (rather than the antecedent sensory-analysis and sensory-storing functions as they inferred).

Näätänen's (1991) defence of MMN's preattentive quality follows on from earlier observations made by Näätänen, Simpson, and Loveless (1982), relating to what is referred as the N2b component. They argued that this more central component (in terms of scalp distribution), followed and partially overlapped the more frontally located MMN component when the participant attended in their experiment, giving the impression that attention had a dramatic effect on MMN.

The possible effects of attention also concerned Stelmack et al. (1977) when reporting the enhanced auditory-evoked responses elicited by introverts to low frequency stimuli of both low and moderate intensity. This concern was subsequently investigated in Stelmack and Achorn's (1985) paper, in which it was reported that participants were asked to either attend or ignore a series of low frequency tones. Their findings echoed those of Stelmack et al.'s previous experiment, with introverts eliciting larger amplitude waves in the 100 to 200 ms period following stimulation, but failed to establish clear differences between attended and unattended conditions. This led Stelmack and Achorn to conclude that the previously identified introvert-extravert differences were not due to attentional mechanisms and appears to further reinforce MMN's suitability as a discriminatory measurement.

Despite the potential for MMN and other exogenous components to provide accurate measures of initial introvert-extravert physiological arousal to the physical properties of presenting stimuli, ERP studies of arousal-oriented activities, such as gambling, focus predominantly upon later, endogenous components. One partial exception to this generalisation is Bartussek, Diedrich, Naumann, and Collett's (1993) study, looking at introvert/extravert brain activity in a pseudo-gambling situation (where tones indicated a win or a loss). Their study found significant introvert-extravert differences for the exogenous P2 and N2 components, with extraverts eliciting the largest P2 and N2 amplitudes overall for 'winning' tones, whereas the introverts responded most strongly to a loss. These responses were intensified as the betting stake increased, prompting Bartussek et al. to suggest these components had emotional significance and that extraverts were more likely to gamble.

However, Bartussek et al.'s (1993) interpretation of their P3 data proved more uncertain, with the trend evident in the P2 and N2 components continuing only for those introverts and extraverts who were highly neurotic. Less neurotic extraverts exhibited the same P3 amplitudes regardless of gambling result, whereas introverted participants with low levels of neuroticism had larger P3 amplitudes for wins. However, these latter findings were not as pronounced as the results for the more neurotic participants – indicating the involvement of less attentional resources (Begleiter et al., 1998) and a distinction that Barnes and Sharda's (1987) study may add some substance to. They showed that compulsive gamblers were significantly more neurotic than non-gamblers, indicating that Bartussek et al.'s P3 findings for the highly neurotic extraverts-introverts may be more important in a gambling context.

Bartussek et al.'s (1993) inference that extraverts may be more inclined to gamble is strengthened by the findings of Hatano and Inagaki (1977). Their more behaviourally-oriented study of the introvert-extravert dimension found that extraverts were more likely to take significantly greater risks while betting in a gambling situation than introverts.

However, despite this empirical support and seemingly sound theoretical basis, the link between extraversion and gambling remains far from clear cut. Barnes and Sharda's (1987) study on compulsive and non-gamblers failed to find any significant relationship between extraversion and gambling. Instead, the Eysenck Personality Inventory (EPI) showed that non-gamblers actually reported a higher mean level of extraversion (13.25) than the compulsive gamblers (11.50).

Barnes and Sharda's (1987) findings, while unexpected, indirectly highlight a criticism previously levelled at the extraversion-introversion personality dimension. Carrigan (1960) suggested this personality continuum was not unidimensional, with extraversion being seen more as 'sociability' by American researchers, whereas their European counterparts identified extraversion more with 'impulsiveness'. Eysenck and Eysenck (1963) acknowledged this by recognising sociability and impulsiveness as distinct elements within extraversion. The concept of extraversion was then further complicated by the consideration of Twain's (1957) earlier work, which suggested 'impulsiveness' was composed of a number of underlying factors. These observations encouraged Eysenck and Eysenck (1977) to broaden the concept of extraversion by breaking down impulsiveness (in its broad sense) into four sub-factors – impulsiveness (specific), risk-taking, non-planning, and liveliness. This refinement has subsequently been supported, with Sipps and Alexander's (1987) work identifying three different forms of extraversion; sociability; impulsivity and non-planning; and finally liveliness, risk-taking, or jocularity.

The 'risk-taking' trait that Sipp and Alexander (1987) identified with extraversion was also of interest to Ansari and Ahmad (1977). Like Barnes and Sharda (1987), Ansari and Ahmad found no correlation between gamblers and a host of personality factors (including extraversion). However, scores relating to 'risk-taking' proved otherwise, with Ansari and Ahmad's findings showing that measures of 'risk-taking' were significantly higher among gamblers than non-gamblers – again suggesting that this trait is quite distinct from extraversion.

Allcock and Grace's (1988) research appears to indirectly support Ansari and Ahmad's (1977) reported association between 'risk-taking' and gambling, through a process of elimination. Their research counters any suggestion that Sipp and Alexander's (1987) second identified type of extraversion, impulsivity, may promote any attraction to gambling – as results indicated that pathological gamblers did not differ significantly from the control group for impulsivity or sensation-seeking.

Accordingly, it may be argued that risk-taking is a trait independent of extraversion – one that appears to have close links with arousal-oriented activities like gambling. Kogan and Wallace's (1964) results appear to provide a degree of support for this notion, identifying a relationship between self-reported levels of anxiety and risk-taking. However, Dahlback (1990) suggests that this was only a weak association, while Reingen (1976) highlighted a potential problem with participants' understanding of Kogan and Wallace's (1964) Choice Dilemma Questionnaire.

Irrespective of these concerns, there appears to be an opportunity for more objective, physiological data to clarify the situation. Accordingly, the aim of this study was to identify any physiological evidence to suggest a difference between extraverted risk-takers and non-risk takers, and how this may be related back to arousal-oriented activities like gambling. Exogenous MMN amplitudes were the primary measurement for this experiment, as previous work looking at personality and gambling has tended to centre upon more endogenous components of the ERP wave. In so doing, this earlier work has considered the individual's perception of the stimulus context, rather than its physical properties – which may also contain clues as to why stimulating environments (like those associated with gambling) are more attractive to some than others. No endogenous P3 activity like that found in Bartussek et al.'s (1993) study was expected, as this is thought to reflect cognitive processing of the stimuli's probabilities amongst other things – a mechanism requiring attention (which was directed towards another task in this study). However, precautionary analysis of this area of the ERP waveform was performed, as more salient stimuli, such as louder tones, may instigate these later cognitive processes (Cahill & Polich, 1992).

It was expected that any physiological differences identified between the extravert groups would be maintained in their responses to relevant self-report questionnaires. More specifically, group differences were expected for responses estimating perceived risk-taking tendencies and current gambling behaviour.

An introvert group was included so that results may be discussed relative to past work. In accordance with previous findings (Stelmack & Campbell, 1974; Stelmack, Achorn, & Michaud, 1977), it was expected that the introvert group would elicit the largest exogenous amplitudes to low frequency tones presented. Past findings (Harkins & Geen, 1975) also indicate that the introvert group should have been more vigilant in its completion of the comprehension test – reflecting a greater ability to attend to the assigned reading task.

Method

Participants

Four hundred and ten first year university students were screened using the Eysenck Personality Questionnaire (Eysenck & Eysenck, 1975) and the Choice Dilemma Questionnaire (Kogan & Wallach, 1964; See Appendix A-1). The scoring of these questionnaires enabled three extreme groups of ten females each to be identified: extravert/risk-takers, extravert/non-risk-takers, and introverts.

Table 1. Eysenck Personality Questionnaire Score Ranges for Groups (with statistical means in parentheses)

	Extravert		
	Risk-Takers	Non-risk-takers	Introverts
EPQ Score Range	17 to 21 (19)	17 to 20 (19.2)	3 to 10 (6.4)

Female participants from a relatively small age range (17 to 29 years) were used due to availability and in an attempt to reduce the number of potentially confounding variables. Studies have shown that females elicit significantly larger ERP amplitudes than males in response to auditory stimuli (Picton, Stuss, Champagne, & Nelson, 1984; Cahill & Polich, 1992), while other research has provided evidence of age-related ERP variations (Friedman, Boltri, Vaughan, & Erlenmeyer-Kimling, 1985). However, Dickerson (1996) notes that more Australian men have difficulties with gambling than women – which may make extrapolations from any findings more difficult.

Instrumentation

An IBM 486 compatible computer was used to generate the auditory stimuli, which were presented binaurally to the participant via headphones, while another IBM 486 compatible computer in an adjoining room recorded the electrophysiological data.

EEG activity was collected from a 10-20 system tin electrode skull-cap with tin earlobe reference and a frontal earth, sampling at 250Hz with a low pass filter of 0.1Hz and a high pass filter of 30Hz. Tin electrodes above and below the right eye were used to monitor electro-oculographic (EOG) activity. All signals were amplified by a Grass Neurodata model 12 acquisition system.

Procedure

Before beginning any experimental work, ethical approval was obtained from the University of Tasmania Human Ethics Committee. This granted, selected participants were invited to attend an hour-long testing session. They were asked not to smoke or drink coffee for three hours before arriving for the session, as recent ingestion of such stimulants has been shown to affect participants' physiology (Smith, Wilson, & Jones, 1983).

Upon arrival, participants were required to fill in a medical questionnaire (see Appendix A-2). Responses were then checked for any potentially confounding variables (such as poor hearing, recent concussion, or drug taking). Once medically cleared, participants were briefed about the experiment verbally and with the aid of an information/consent form (see Appendix A-3), full consent was obtained.

Participants were physically prepared by having electrodes attached above and below the right eye to monitor EOG activity – with all resistances kept below 5 KΩ. An electrode skull-cap was then fitted, preparing the midline sites F_Z, C_Z, and P_Z (with an earth at FP_Z). All sites were referenced to the participant's earlobe and had resistances under 10 KΩ.

Participants were presented with stimuli binaurally through headphones in blocks of 500. This was done while the participants read a standardised passage of text so that the tones were unattended. Standard tones were 50ms in duration (with rise time of 10 ms), at 55 dB intensity, with a pitch of 1000 Hz. Rare tones were randomly distributed (but no less than five tones apart), lasting 50ms (rise time of 10 ms), at either 55 or 80 dB intensity, both with a pitch of 500 Hz. The standard tone was presented at a probability rate of 0.7, whereas the two rare tones (55 and 80 dB) each had a probability of 0.15.

Each EEG recording covered a 1000 ms epoch (commencing 100 ms before stimulus onset) and was recorded by an IBM-compatible 486 computer in an adjoining room to the participants'. One hundred samples were required for each rare tone, with recordings rejected if the recorded EOG amplitude was more than 70μV. The computer program then calculated ERP waveforms from these EEG samples.

Once 100 EEG samples for each tone had been collected, participants were invited to return to the preparation room and have all testing equipment removed. Participants were then finally asked to complete the South Oaks Gambling Screen (Lesieur & Blume, 1987) and a multiple choice questionnaire relating to the passage of text they had read in the testing room (see Appendix A-4). Participants were forewarned of this comprehension test in the hope that this would focus their attention on the text.

Design and Data Analysis

This study represents a 3×2×3 mixed factorial design, involving the between group variable 'Group' (extravert 'Risk-takers', extravert 'Non-Risk-takers', and 'Introverts'), as well as the within group factors, 'Tone' (low/high) and 'Site' ($F_Z/C_Z/P_Z$). Dependent measures include the participant's averaged MMN and P3 amplitudes (see Appendix B for raw data).

MMN and P3 amplitudes were separately analysed with a 3×2×3, between-groups, within-subjects ANOVA identifying any possible main effects or interactions between 'Group', 'Tone', and 'Site' (significant at the $p<0.05$ level). Appropriate use of post-hoc Newman-Keuls tests were made to highlight significant differences between individual means (again significant at the $p<0.05$ level).

Specific hypotheses were also investigated with one-way and two-way ANOVAs (significant at the $p<0.05$ level). These focused on group differences in the participants' CDQ scores, their South Oaks Gambling Screen (SOGS) scores, as well as number of questions attempted and percentage correct for the comprehension test.

Results

Grand Mean Waveforms

Grand mean waveforms for participant responses to the common stimuli and the two deviant tones ('High' and 'Low') are shown in Figure 1 below. The 'common' waveform represents each group's average EEG response to the standard tones (with between 500 and 1000 stimulus-specific EEG samples recorded from each participant), whereas the group waveforms for the deviant tones are based on approximately 100 samples from each participant. As Figure 1 illustrates, the high deviant tones elicited the most pronounced ERP activity, particularly around the P2 and P3 area of the waveforms.

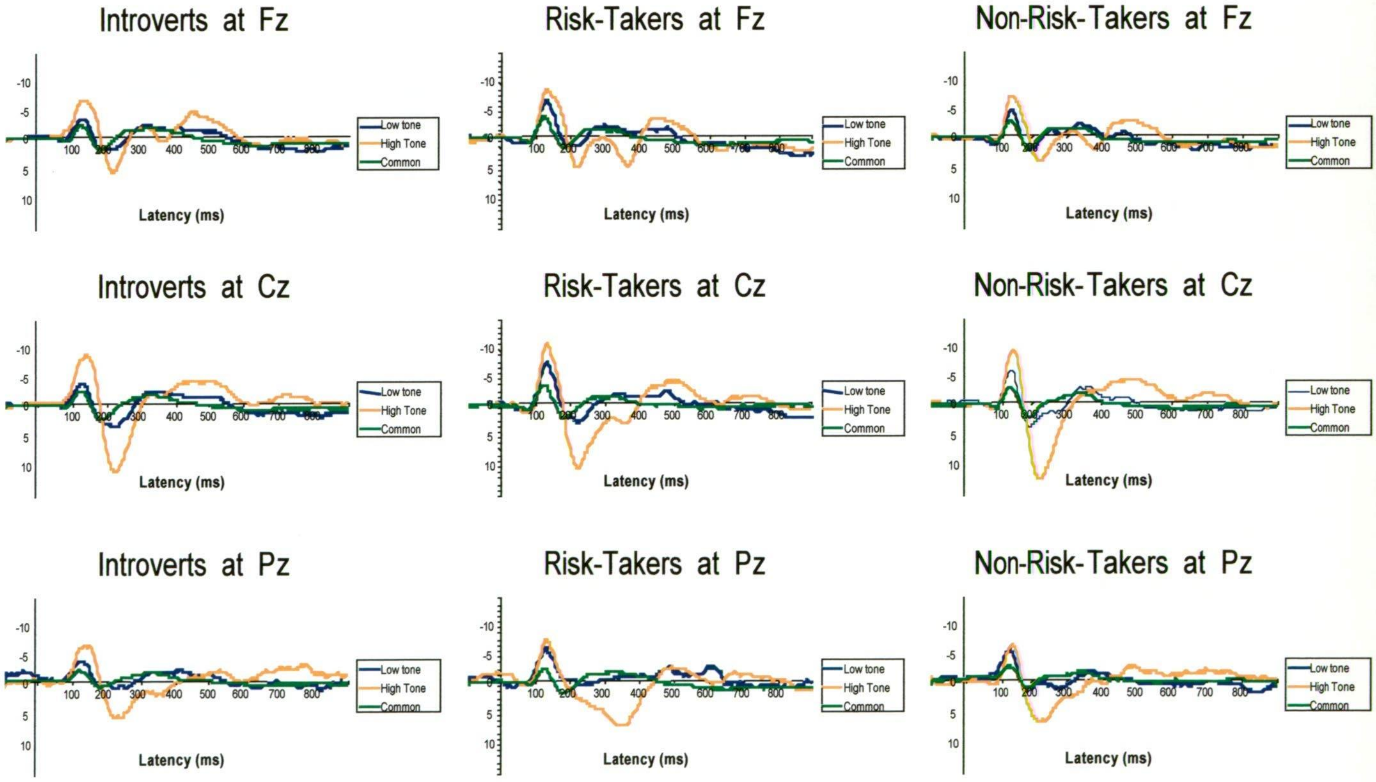

Figure 1: Grand Mean Waveforms (Y axis units are in μV).

Grand Mean Difference Waveforms

The grand mean difference waveforms for each group (shown in Figure 2) were calculated for each site by subtracting the group's grand mean ERP waveform for the standard tone from the grand mean ERP waveform for each of the rare tones. As Figure 2 illustrates, the ERPs for the three groups share similar features across a number of condition and site combinations, with the Risk-takers' waveform tending to exhibit the largest amplitudes. Similarities between groups extend to a more pronounced waveform (in terms of amplitude) for the louder (80 dB) 'High' condition.

However, upon closer inspection, it is evident that the three 'High' graphs also contain a number of differences. These differences are largely relative to the extravert Risk-taker waveform, which is characterised by a more prominent P3 peak at F_z and C_z than the other two groups. The extravert Risk-taker ERP again differs in amplitude from the other waveforms at P_z for the 'High' condition, only this time with a noticeable difference in latency as well. Here, the waveform for the extravert Risk-taker group displays what appears to be a larger P3 component than the P2-like components elicited by the Non-risk-takers and Introverts.

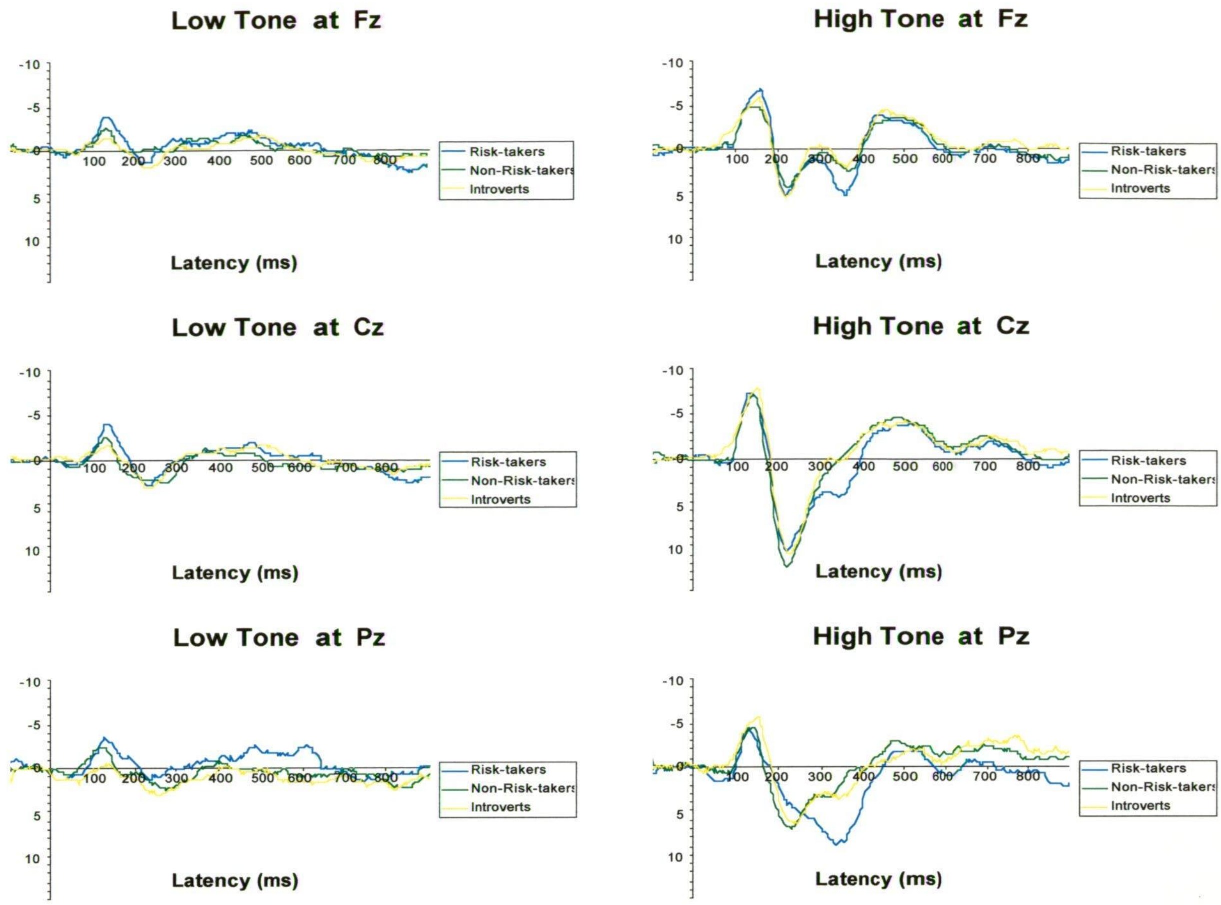

Figure 2: Grand Mean Difference Waveforms (Y axis units are in μV).

Mismatch Negativity Analysis

The grand mean difference waveforms for each rare condition (see Figure 2) were considered before selecting an appropriate range of MMN amplitudes to be averaged for each group. Each group's waveform has an exogenous negative peak amplitude between 100 and 200 ms, irrespective of the condition or site. Accordingly, this epoch was chosen to provide the data for each group's average MMN amplitude.

The average MMN component elicited for 'Low' (55 dB and 500 Hz) and 'High' (80 dB and 500 Hz) rare tones was analysed using a three-way ANOVA with repeated measures (see Appendix C-1). Analysis of this average MMN component did not identify any significant main effect for 'Group' [$F(2,27) = 0.44$, $p=0.65$], but did reveal a significant main effect for 'Tone' [F(1,27) = 32.45, p<0.05], with 'High' rare tones (-2.96 μV) eliciting significantly greater MMN amplitudes than those in response to 'Low' rare tones (-0.94 μV). 'Site' [F(2,54) = 6.64, p<0.05] also showed a significant main effect, with Newman-Keuls post-hoc tests indicating that P_z activity (-1.39 μV) was significantly lower than at F_z (-2.40 μV) and C_z (-2.04 μV).

Newman-Keuls post hoc examination of the significant interaction between 'Group' and 'Tone' [F(2,27) = 3.80, p<0.05] revealed a number of significant differences. As Figure 3 shows, when 'Low' tones were presented, extravert 'Risk-takers' (-1.77 μV) elicited a significantly more negative MMN amplitude than 'Introverts' (-0.24 μV). Significant differences were also evident within groups across the two rare conditions, with 'Non-risk-taker' extraverts responding significantly more to the 'High' condition (-2.34 μV) than the 'Low' condition (-0.81 μV). The 'Introvert' group echoed this, with their reaction to the 'High' tone (-3.62 μV) displaying a significantly larger amplitude than that of the 'Low' tone (-0.24 μV).

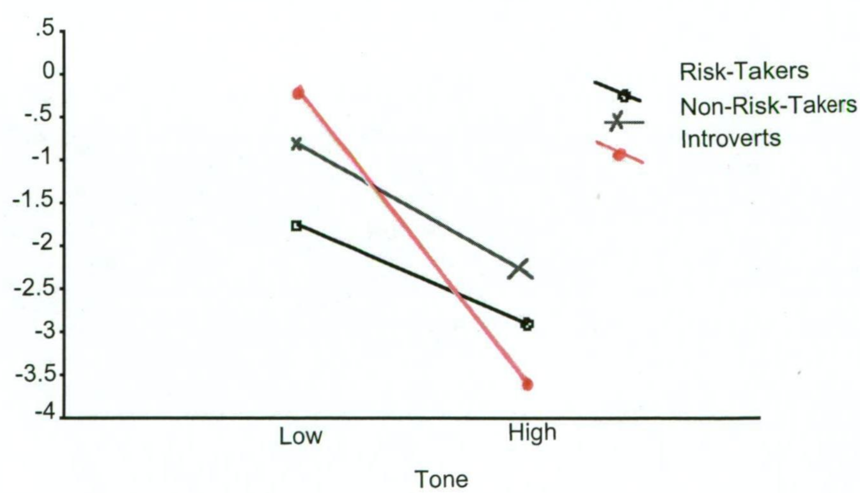

Figure 3: The effect of high and low tone upon MMN Amplitudes (in μV) across groups.

A significant interaction was also found between 'Tone' and 'Site' [F(2,54) = 5.25, p<0.05]. Newman-Keuls post hoc analysis highlighted that for the 'High' condition, Pz (-1.97 μV) exhibited a significantly smaller MMN amplitude than that recorded at F_z (-3.70 μV) or Cz (-3.20 μV).

Analysis of the P3 Component

Initial observations of the grand mean difference waveforms for the 'High' deviant tone suggested group differences may also exist within the P3 component, with noticeable discrepancies between the extravert Risk-taker waveform and those waveforms associated with the other two groups. These differences were not apparent in the waveforms elicited in response to the low deviant tones and so a two-way ANOVA was conducted with 'Group' and 'Site' as independent variables, while the dependent variable was restricted to 'High' tone P3 amplitudes. This analysis (see Appendix C-3) revealed a strong trend toward group differences [F(2,27) = 26.69, p=0.055], as well as a main effect for 'Site' [F(2,54) = 6.98, p<0.05]. Newman-Keuls post hoc analysis indicated that the average P3 amplitude elicited by the extravert Risk-taker group across the three sites (4.28 μV) was significantly larger than those for the extravert Non-risk-taker (1.50 μV). The extravert Risk-taker's average P3 amplitude also showed a trend towards being significantly larger (p = 0.07) than that elicited by the Introvert group (1.20 μV) – significance presumably prevented by larger standard deviations for these two groups.

Analysis of Choice Dilemma Questionnaire

A main effect for 'Group' [F(2,27) = 20.05, p<0.05] was found when analysing the participants' CDQ scores with a one-way ANOVA (see Appendix C-5). In accordance with expectations, Newman-Keuls post hoc analysis showed that the three group scores (shown in Table 1) were significantly different from each other. Extravert 'Risk-takers' were significantly higher than the 'Introverts', who in turn were significantly higher than the extravert 'Non-Risk-takers'.

Table 2. Group CDQ Scores (with SDs in parentheses)

	Extravert		
	Risk-Takers	Non-risk-takers	Introverts
CDQ Score	59 (3.33)	90 (9.41)	73.80 (16.49)

Analysis of South Oaks Gambling Screen

No main effect for 'Group' was found when analysing the participants' SOGS scores with a one-way ANOVA (see Appendix C-5), with Table 2 showing the very low scores recorded for each group. No participant scored more than 1/20 (where a score of 5 is clinically significant).

Table 3. Group SOG Scores (with SDs in parentheses).

	Extravert		
	Risk-Takers	Non-risk-takers	Introverts
SOG Score	0.2 (0.42)	0.3 (0.48)	0.1 (0.32)

Analysis of Comprehension Questionnaires

The comprehension questionnaires administered to each participant after the testing session were collectively analysed (see Appendix C-6). Group means were calculated for the number of questions each participant attempted and the percentage of these attempted questions that were correct (see Table 3). A one-way ANOVA looking for 'Group' differences in the number of questions attempted (reflecting how much of the book the participant had read) was then completed. This analysis showed a trend towards significant 'Group' differences [$F(2,27) = 3.07$, $p=0.06$], with Newman-Keuls post hoc analysis highlighting the fact that the extravert Non-risk-takers answered significantly fewer questions than the extravert Risk-takers and the introverts.

Table 3 also highlights the fact that the introvert group not only answered the highest number of questions on average, but also was the most accurate in their responses to the comprehension test. However, the accuracy of the introverts was not significantly greater than that achieved by the extravert Non-risk-taker or the extravert Risk-taker groups.

Table 4. Number of Comprehension Questions Answered and Percentage Correct (with SDs in parentheses).

	Extravert		
	Risk-Takers	Non-risk-takers	Introverts
Questions answered	7.4 (3.47)	4.6 (1.96)	7.6 (3.41)
Percentage correct	94.75% (11.33)	95.78% (8.92)	96.67% (8.05)

Discussion

The results generally did not bear out the expected exogenous physiological differences between the extraverted risk-taking and non-risk-taking groups, but exhibited other, unexpected, P3 differences. Perhaps not surprisingly, group differences were also absent for reported involvement in arousal-oriented activities (measured by the South Oaks Gambling Screen). However, results pertaining to the participants' ability to attend (involving the comprehension questionnaire) were in accordance with expectations, with the introvert group shown to be more vigilant and accurate when attending to a task.

Mismatch Negativity Analysis

The MMN results provided a limited basis from which to argue the existence of physiological differences between extravert risk-takers and non-risk-takers, with no main effect for Group. Perhaps the most notable aspect of the MMN analysis was the Group–Tone interaction, which showed that the extravert risk-taking group produced significantly larger MMN amplitudes than the introvert group in response to Low tones (500 Hz at 55 dB). Stelmack et al. (1977) found the opposite to be true in their experiment using the same low tone, with introverts producing significantly larger N1-P1 amplitudes. It was initially thought that this difference may have been influenced by the fact that the participants attended to the alternating high (8000 Hz at 55 dB) and low (500 Hz at 55 dB) tones being presented. This was formally noted by Stelmack and Achorn (1985) who replicated these findings in the absence of attention. However, both these experiments did not employ rapid changes in stimulus intensity (or decibel level) and did not create any participant uncertainty with random stimuli presentation, reducing the likelihood of observing anything resembling MMN and excluding elements likely to be involved with gambling.

It is also interesting to note that in Bartussek et al.'s (1993) gambling study, where risk was a factor, the N2 amplitudes they recorded in response to 75 dB tones of either 800 or 1600 Hz (indicating a win or loss) were always greater for extraverts. Bartussek et al.'s interpretation of introvert responses were relative to that group's reactions – suggesting that predictions (based upon Stelmack's (1980; 1990) and others work) of larger introvert responses to moderate stimuli (60 to 80 dB) may still be challenged.

This issue aside, the data appears to be free of any N2b effects. This confidence stems from the identified main effect for 'Site', which showed the greatest exogenous ERP activity (between 100 and 200 ms) was evident in the frontal regions of the brain. Should the more central parts of the brain have been found to be most active, then there would have been grounds to suggest the influence of attention and the N2b component (Näätänen, Simpson, & Loveless, 1982; Näätänen, 1991).

Analysis of the P3 Component

The trend towards a main effect for 'Group' within the 'High' tone data for the P3 component was unexpected, as it suggests an awareness of the changing stimuli and subsequent processing of its probability (Begleiter et al., 1998). However, post hoc analysis of this data did provide perhaps the most meaningful physiological difference between the two extravert groups, with the risk-taker group eliciting significantly larger

P3 amplitudes than the non-risk-taking group (and the introvert group) for loud rare tones. This suggests that the arousal-provoking, louder tones were not only more salient, but perhaps had greater meaning for the risk-taking group – which would imply an attraction to arousal-oriented activities such as gambling.

The possibility that P3 amplitudes elicited in response to the High tone may be influenced by the groups' risk-taking tendencies may be further strengthened when it is considered that the P3 amplitude for the introvert group was in-between those recorded for the two extraverted groups. This same hierarchical relationship is evident in the participant responses to the Choice Dilemma Questionnaire (CDQ), with the introvert group's score again splitting those for the extraverted groups and suggesting a positive correlation between P3 amplitude and risk-taking.

Analysis of the Choice Dilemma Questionnaire and the South Oaks Gambling Screen

Risk-taking's autonomy appears to be reinforced by the fact that the introvert group separated the two extravert groups on the CDQ scale. Not only were the extravert groups distinguished on this scale to begin with, but the introvert group was shown to incorporate a range of risk-taking attitudes – evidenced by a standard deviation that was far larger than those recorded for the extravert groups. Such variation in risk-taking tendencies within the introvert group adds to the notion that risk-taking remains a characteristic independent of the introversion-extraversion personality dimension. This autonomy is further supported by Ansair and Ahmad's (1977) results, which indicated that age, socio-economic status, religious background, and living environment (urban or rural), also have no apparent influence over a person's risk-taking tendencies.

However, the CDQ measurements of risk-taking failed to translate into any recognisable trend with regard to reported gambling. The very low group scores for the South Oaks Gambling Screen (SOGS) indicate that few participants, regardless of group, are inclined to gamble or have gambling-related problems. It may well have been more appropriate to have used a questionnaire which focused more on the participant's gambling attitudes, rather than their actual gambling behaviour. Regardless, suspicions are that the lack of significant findings relating to gambling may also relate to the sex of the participants – given Dickerson's (1996) observations that Australian men are more likely to be involved with problem gambling and Kohler's (1996) conclusion that men are greater risk-takers. However, in defence, it should be noted that Kogan and Wallach (1964) argue that women's responses to the CDQ are more likely to be consistent with their eventual actions. This suggestion, combined with the fact that the extravert risk-taker group had a CDQ mean below a 50% chance (of success), suggests that 'risk-takers' is still a valid grouping within women.

Analysis of the Comprehension Test

The exclusive use of female participants may also be validated when discussing the results for the comprehension test – enabling a direct comparison with Harkins and Geen's (1974) work relating to female personality and vigilance. In accordance with Harkins and Geen's findings, results showed that introverts were more thorough and attentive than extraverts when responding to the comprehension questions. The introvert group answered more questions on average than the two extraverted groups and had higher rate of accuracy as well – inferring better concentration and attention to the reading task.

Conclusion

The data showed no support for an exogenous ERP basis for risk-taking. Yet the noted inconsistencies between Stelmack's (1980; 1990) and Bartussek et al.'s (1993) findings suggest that even the most stable and researched personality traits (namely the introvert-extravert dimension) remain physiologically unpredictable. This naturally casts doubt over the physiological hypotheses to begin with, confining surety of expectations to more behavioural aspects. However, here too the results were mixed, with the introverts fulfilling expectations of greater vigilance and concentration, whereas no group difference was reported for gambling activity.

While accepting the limitations of these results, it is important that other relevant findings, such as those relating to the personality questionnaires and later components of the ERP waveform, are not undervalued. The potential relationship between 'risk-taking' and the P3 component is of particular interest, as it appears to support the relatively recent focus adopted by ERP gambling research, concerning the importance of the stimuli's meaning and context. This suggests an individual's perception of the stimuli's meaning and context (involving endogenous ERP components) has greater influence over their attraction to arousal-based activities than their reaction to the physical (or exogenous) properties of the stimuli.

However, even these more robust findings are still subject to design restrictions, making further generalisations difficult. The youthful age range and the use of one sex, while necessary to reduce the number of confounding variables, limit the generalisability of any findings – particularly in view of Dickerson's (1996) and Kohler's (1996) conclusions.

Despite these shortcomings, the experiment was valuable in suggesting a physiological basis for the more specific characteristic of risk-taking. As with other forms of current ERP research, particular promise appears to lie with later, endogenous ERP components; components which may well hold the definitive answers for risk-taking and people's attraction to activities like gambling.

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Name:
Phone No:
Prac No:
Sex:
Age:

Appendix E

Choice Dilemmas Procedure

OPINION QUESTIONNAIRE II

Instructions. On the following pages, you will find a series of situations that are likely to occur in everyday life. The central person in each situation is faced with a choice between two alternative courses of action, which we might call X and Y. Alternative X is more desirable and attractive than alternative Y, but the probability of attaining or achieving X is less than that of attaining or achieving Y.

For each situation on the following pages, you will be asked to indicate the minimum odds of success you would demand before recommending that the more attractive or desirable alternative, X, be chosen.

Read each situation carefully before giving your judgment. Try to place yourself in the position of the central person in each of the situations. There are twelve situations in all. Please do not omit any of them.

1. Mr. A, an electrical engineer, who is married and has one child, has been working for a large electronics corporation since graduating from college five years ago. He is assured of a lifetime job with a modest, though adequate, salary, and liberal pension benefits upon retirement. On the other hand, it is very unlikely that his salary will increase much before he retires. While attending a convention, Mr. A is offered a job with a small, newly founded company which has a highly uncertain future. The new job would pay more to start and would offer the possibility of a share in the ownership if the company survived the competition of the larger firms.

Imagine that you are advising Mr. A. Listed below are several probabilities or odds of the new company's proving financially sound.

Please check the lowest *probability that you would consider acceptable to make it worthwhile for Mr. A to take the new job.*

____ The chances are 1 in 10 that the company will prove financially sound.
____ The chances are 3 in 10 that the company will prove financially sound.
____ The chances are 5 in 10 that the company will prove financially sound.
____ The chances are 7 in 10 that the company will prove financially sound.
____ The chances are 9 in 10 that the company will prove financially sound.
____ Place a check here if you think Mr. A should *not* take the new job no matter what the probabilities.

2. Mr. B, a 45-year-old accountant, has recently been informed by his physician that he has developed a severe heart ailment. The disease would be sufficiently serious to force Mr. B to change many of his strongest life habits — reducing his work load, drastically changing his diet, giving up favorite leisure-time pursuits. The physician suggests that a delicate medical operation could be attempted which, if successful, would completely relieve the heart condition. But its success

Imagine that you are advising Mr. B. Listed below are several probabilities or odds that the operation will prove successful.

Please check the lowest *probability that you would consider acceptable for the operation to be performed.*

____ Place a check here if you think Mr. B should *not* have the operation no matter what the probabilities.
____ The chances are 9 in 10 that the operation will be a success.
____ The chances are 7 in 10 that the operation will be a success.
____ The chances are 5 in 10 that the operation will be a success.
____ The chances are 3 in 10 that the operation will be a success.
____ The chances are 1 in 10 that the operation will be a success.

3. Mr. C, a married man with two children, has a steady job that pays him about \$6000 per year. He can easily afford the necessities of life, but few of the luxuries. Mr. C's father, who died recently, carried a \$4000 life insurance policy. Mr. C would like to invest this money in stocks. He is well aware of the secure "blue-chip" stocks and bonds that would pay approximately 6% on his investment. On the other hand, Mr. C has heard that the stocks of a relatively unknown Company X might double their present value if a new product currently in production is favorably received by the buying public. However, if the product is unfavorably received, the stocks would decline in value.

Imagine that you are advising Mr. C. Listed below are several probabilities or odds that Company X stocks will double their value.

Please check the lowest *probability that you would consider acceptable for Mr. C to invest in Company X Stocks.*

____ The chances are 1 in 10 that the stocks will double their value.
____ The chances are 3 in 10 that the stocks will double their value.
____ The chances are 5 in 10 that the stocks will double their value.
____ The chances are 7 in 10 that the stocks will double their value.
____ The chances are 9 in 10 that the stocks will double their value.
____ Place a check here if you think Mr. C should *not* invest in Company X stocks, no matter what the probabilities.

4. Mr. D is the captain of College X's football team. College X is playing its traditional rival, College Y, in the final game of the season. The game is in its final seconds, and Mr. D's team, College X, is behind in the score. College X has time to run one more play. Mr. D, the captain, must decide whether it would be best to settle for a tie score with a play which would be almost certain to work or, on the other hand, should he try a more complicated and risky play which could bring victory if it succeeded, but defeat if not.

Imagine that you are advising Mr. D. Listed below are several probabilities or odds that the risky play will work.

Please check the lowest *probability that you would consider acceptable for the risky play to be attempted.*

Appendix A: Choice Dilemma Questionnaire (A-1)

____ Place a check here if you think Mr. D should *not* attempt the risky play no matter what the probabilities.
____ The chances are 9 in 10 that the risky play will work.
____ The chances are 7 in 10 that the risky play will work.
____ The chances are 5 in 10 that the risky play will work.
____ The chances are 3 in 10 that the risky play will work.
____ The chances are 1 in 10 that the risky play will work.

5. Mr. E is president of a light metals corporation in the United States. The corporation is quite prosperous, and has strongly considered the possibilities of business expansion by building an additional plant in a new location. The choice is between building another plant in the U.S., where there would be a moderate return on the initial investment, or building a plant in a foreign country. Lower labor costs and easy access to raw materials in that country would mean a much higher return on the initial investment. On the other hand, there is a history of political instability and revolution in the foreign country under consideration. In fact, the leader of a small minority party is committed to nationalizing, that is, taking over, all foreign investments.

Imagine that you are advising Mr. E. Listed below are several probabilities or odds of continued political stability in the foreign country under consideration.

Please check the lowest *probability that you would consider acceptable for Mr. E's corporation to build a plant in that country.*

____ The chances are 1 in 10 that the foreign country will remain politically stable.
____ The chances are 3 in 10 that the foreign country will remain politically stable.
____ The chances are 5 in 10 that the foreign country will remain politically stable.
____ The chances are 7 in 10 that the foreign country will remain politically stable.
____ The chances are 9 in 10 that the foreign country will remain politically stable.
____ Place a check here if you think Mr. E's corporation should *not* build a plant in the foreign country, no matter what the probabilities.

6. Mr. F is currently a college senior who is very eager to pursue graduate study in chemistry leading to the Doctor of Philosophy degree. He has been accepted by both University X and University Y. University X has a world-wide reputation for excellence in chemistry. While a degree from University X would signify outstanding training in this field, the standards are so very rigorous that only a fraction of the degree candidates actually receive the degree. University Y, on the other hand, has much less of a reputation in chemistry, but almost everyone admitted is awarded the Doctor of Philosophy degree, though the degree has much less prestige than the corresponding degree from University X.

Imagine that you are advising Mr. F. Listed below are several probabilities or odds that Mr. F would be awarded a degree at University X, the one with the greater prestige.

Please check the lowest *probability that you would consider acceptable to make it worthwhile for Mr. F to enroll in University X rather than University Y.*

____ Place a check here if you think Mr. F should *not* enroll in University X, no matter what the probabilities.
____ The chances are 9 in 10 that Mr. F would receive a degree from University X.
____ The chances are 7 in 10 that Mr. F would receive a degree from University X.
____ The chances are 5 in 10 that Mr. F would receive a degree from University X.
____ The chances are 3 in 10 that Mr. F would receive a degree from University X.
____ The chances are 1 in 10 that Mr. F would receive a degree from University X.

7. Mr. G, a competent chess player, is participating in a national chess tournament. In an early match he draws the top-favored player in the tournament as his opponent. Mr. G has been given a relatively low ranking in view of his performance in previous tournaments. During the course of his play with the top-favored man, Mr. G notes the possibility of a deceptive though risky maneuver which might bring him a quick victory. At the same time, if the attempted maneuver should fail, Mr. G would be left in an exposed position and defeat would almost certainly follow.

Imagine that you are advising Mr. G. Listed below are several probabilities or odds that Mr. G's deceptive play would succeed.

Please check the lowest *probability that you would consider acceptable for the risky play in question to be attempted.*

____ The chances are 1 in 10 that the play would succeed.
____ The chances are 3 in 10 that the play would succeed.
____ The chances are 5 in 10 that the play would succeed.
____ The chances are 7 in 10 that the play would succeed.
____ The chances are 9 in 10 that the play would succeed.
____ Place a check here if you think Mr. G should *not* attempt the risky play, no matter what the probabilities.

8. Mr. H, a college senior, has studied the piano since childhood. He has won amateur prizes and given small recitals, suggesting that Mr. H has considerable musical talent. As graduation approaches, Mr. H has the choice of going to medical school to become a physician, a profession which would bring certain prestige and financial rewards; or entering a conservatory of music for advanced training with a well-known pianist. Mr. H realizes that even upon completion of his piano studies, which would take many more years and a lot of money, success as a concert pianist would not be assured.

Imagine that you are advising Mr. H. Listed below are several probabilities or odds that Mr. H would succeed as a concert pianist.

Please check the lowest *probability that you would consider acceptable for Mr. H to continue with his musical training.*

____ Place a check here if you think Mr. H should *not* pursue his musical training, no matter what the probabilities.
____ The chances are 9 in 10 that Mr. H would succeed as a concert pianist.

____ The chances are 5 in 10 that Mr. H would succeed as a concert pianist.
____ The chances are 3 in 10 that Mr. H would succeed as a concert pianist.
____ The chances are 1 in 10 that Mr. H would succeed as a concert pianist.

9. Mr. J is an American captured by the enemy in World War II and placed in a prisoner-of-war camp. Conditions in the camp are quite bad, with long hours of hard physical labor and a barely sufficient diet. After spending several months in this camp, Mr. J notes the possibility of escape by concealing himself in a supply truck that shuttles in and out of the camp. Of course, there is no guarantee that the escape would prove successful. Recapture by the enemy could well mean execution.

Imagine that you are advising Mr. J. Listed below are several probabilities or odds of a successful escape from the prisoner-of-war camp.

Please check the lowest *probability that you would consider acceptable for an escape to be attempted.*

____ The chances are 1 in 10 that the escape would succeed.
____ The chances are 3 in 10 that the escape would succeed.
____ The chances are 5 in 10 that the escape would succeed.
____ The chances are 7 in 10 that the escape would succeed.
____ The chances are 9 in 10 that the escape would succeed.
____ Place a check here if you think Mr. J should *not* try to escape no matter what the probabilities.

10. Mr. K is a successful businessman who has participated in a number of civic activities of considerable value to the community. Mr. K has been approached by the leaders of his political party as a possible congressional candidate in the next election. Mr. K's party is a minority party in the district, though the party has won occasional elections in the past. Mr. K would like to hold political office, but to do so would involve a serious financial sacrifice, since the party has insufficient campaign funds. He would also have to endure the attacks of his political opponents in a hot campaign.

Imagine that you are advising Mr. K. Listed below are several probabilities or odds of Mr. K's winning the election in his district.

Please check the lowest *probability that you would consider acceptable to make it worthwhile for Mr. K to run for political office.*

____ Place a check here if you think Mr. K should *not* run for political office no matter what the probabilities.
____ The chances are 9 in 10 that Mr. K would win the election.
____ The chances are 7 in 10 that Mr. K would win the election.
____ The chances are 5 in 10 that Mr. K would win the election.
____ The chances are 3 in 10 that Mr. K would win the election.
____ The chances are 1 in 10 that Mr. K would win the election.

appointment by a major university laboratory. As he contemplates the next five years, he realizes that he might work on a difficult, long-term problem which, if a solution could be found, would resolve basic scientific issues in the field and bring high scientific honors. If no solution were found, however, Mr. L would have little to show for his five years in the laboratory, and this would make it hard for him to get a good job afterwards. On the other hand, he could, as most of his professional associates are doing, work on a series of short-term problems where solutions would be easier to find, but where the problems are of lesser scientific importance.

Imagine that you are advising Mr. L. Listed below are several probabilities or odds that a solution would be found to the difficult, long-term problem that Mr. L has in mind.

Please check the lowest *probability that you would consider acceptable to make it worthwhile for Mr. L to work on the more difficult long-term problem.*

____ The chances are 1 in 10 that Mr. L would solve the long-term problem.
____ The chances are 3 in 10 that Mr. L would solve the long-term problem.
____ The chances are 5 in 10 that Mr. L would solve the long-term problem.
____ The chances are 7 in 10 that Mr. L would solve the long-term problem.
____ The chances are 9 in 10 that Mr. L would solve the long-term problem.
____ Place a check here if you think Mr. L should *not* choose the long-term, difficult problem, no matter what the probabilities.

12. Mr. M is contemplating marriage to Miss T, a girl whom he has known for a little more than a year. Recently, however, a number of arguments have occurred between them, suggesting some sharp differences of opinion in the way each views certain matters. Indeed, they decide to seek professional advice from a marriage counselor as to whether it would be wise for them to marry. On the basis of these meetings with a marriage counselor, they realize that a happy marriage, while possible, would not be assured.

Imagine that you are advising Mr. M and Miss T. Listed below are several probabilities or odds that their marriage would prove to be a happy and successful one.

Please check the lowest *probability that you would consider acceptable for Mr. M and Miss T to get married.*

____ Place a check here if you think Mr. M and Miss T should *not* marry, no matter what the probabilities.
____ The chances are 9 in 10 that the marriage would be happy and successful.
____ The chances are 7 in 10 that the marriage would be happy and successful.
____ The chances are 5 in 10 that the marriage would be happy and successful.
____ The chances are 3 in 10 that the marriage would be happy and successful.
____ The chances are 1 in 10 that the marriage would be happy and successful.

University of Tasmania
Department of Psychology

Medical History Questionnaire

NAME...

AGE..PHONE..

Do you; A. Smoke Cigarettes................................ Yes ☐ No ☐
B. Use or have experimented with either drugs or marijuana ....

....Yes ☐ No ☐

Have you ever been a patient in a Mental hospital?......... Yes ☐ No ☐

Have you ever been a patient in any other hospital ?......... Yes ☐ No ☐

HAVE YOU EVER HAD OR ARE YOU NOW SUFFERING FROM ANY OF THE FOLLOWING;

Fits or Convulsions.......................... Yes ☐ No ☐

Epilepsy.. Yes ☐ No ☐

Giddiness..................................... Yes ☐ No ☐

Concussion.................................... Yes ☐ No ☐

Severe Head Injury.......................... Yes ☐ No ☐

Loss of Consciousness....................... Yes ☐ No ☐

CURRENT MEDICATION

Are you taking any medications at present ? ...... Yes ☐ No ☐
If YES, which Drugs are you taking?

....

....

HEARING

Have you any hearing difficulties? ...... Yes ☐ No ☐
If YES, indicate hearing defects ....

Appendix A: Medical Questionnaire (A-2)

DRINKING HISTORY

On how many days last week did you drink alcohol ?...
- ☐ None
- ☐ One or Two days
- ☐ Five or Six Days
- ☐ Every Day

Do you usually drink..
- ☐ Never
- ☐ During the Week
- ☐ Friday Night
- ☐ Week Ends Only

When you drink is it Normally...............................
- ☐ Light Beer
- ☐ Beer or Cider
- ☐ Wine
- ☐ Mixed spirits
- ☐ Straight Spirits

On a day when you drink, how many drinks would you usually have?
- ☐ One or Two
- ☐ Three to Five
- ☐ Five to Eight
- ☐ Eight to Twelve
- ☐ More than Twelve

How long have you been drinking at this level ?...........
- ☐ Weeks
- ☐ Months
- ☐ Years

Do you get drunk?..
- ☐ Never
- ☐ Rarely
- ☐ Once a Month
- ☐ Once a Week
- ☐ More Frequently

Does your father get drunk?.......................................
- ☐ Never
- ☐ Rarely
- ☐ Once a Month
- ☐ Once a Week
- ☐ More Frequently

Does your Mother get drunk?.................................
- ☐ Never
- ☐ Rarely
- ☐ Once a Month
- ☐ Once a Week
- ☐ More Frequently

Do you have any relatives whom you would consider to be alcoholic?

Yes ☐ No ☐

If YES, How many and what relationship are they to you? ....

....

....

OTHER INFORMATION

How often do you smoke Cigarettes ?.................
- ☐ Never
- ☐ Less than 10 per day
- ☐ 10 to 20 per day
- ☐ 20 to 40 per day
- ☐ Over 40 per day

Note:

It is a formal requirement of the Ethics Committee of the University of Tasmania that the information provided on this questionnaire be held under security to comply with confidentiality regulations and to protect your privacy. You can be assured that information will be available only to the principal researcher and not to any other party. The questionnaire will be destroyed following the completion of the project.

Thankyou for your participation.

Appendix A: Information/Consent Form (A-3)

University of Tasmania

School of Psychology

Cognitive Psychophysiology Research

Participant Consent Form

The research carried out in the Cognitive Electroencephalographic Research Laboratory includes a number continuing research projects. Our studies are concerned with understanding more about the nature of cogni processes, brain activity, and a variety of related phenomena. The success of our research depends, in large measure, upon the assistance of volunteers such as yourself. We would like to extend our appreciation to yo for your participation in this study today.

If you are interested in being a participant in this research, please sign and date this form after carefully reac the following section:

NAME...

Telephone Number...

Today I am volunteering to participate in a research study that involves the presentation of auditory stimuli headphones. I understand that this experiment involves the recording of electrical activity (ERPs) from my brain which will be detected via electrodes non invasively placed on my scalp (the electrodes are contained within a cap which will be placed on my head). In order to place the electrodes, I understand that small portions of my scalp will be washed with an alcohol preparation and may be attached earlier with either sticking plaster (micropore) or via an electrode skull cap.. [*These event-related potentials will occur in response to some stimuli presented to you. Because we are interested in the nature of your brain's response the stimuli, specific instructions about how you should attend to the stimuli will be given throughout the duration of the experiment.*]. I understand that the person carrying out the experiment will give me specific instruction about what to attend to for the duration of the experiment. I will listen carefully to the instructio given and will ask the experimenter to repeat or explain them if I have any concerns.

- I have read and understood the "Information Sheet" for this study.
- The nature and possible effects of the study have been explained to me.
- Any questions that I have asked have been answered to my satisfaction.
- I agree that research data gathered for the study may be published provided that I cannot be identified as subject.

I understand that I may withdraw from the experiment at any time with no prejudice. I also underst that following completion of all experimental sessions (or before if I withdraw from the experiment) the ful procedure of the experiment will be explained to me.

I...have read and understood the above information in regard to this research project and agree to participate in the experiment of my own free will and choice. I understand my rights in regard to my ongoing participation in this projec

Signed...
Date...

I have explained this project and the implications of participation in it to this volunteer and I believe the consent is informed and that he/she understands the implications of participation.

Name of investigator ....
Signature of investigator .... **Date** ....

Appendix A: Reading Comprehension Test (A-4)

Reading Questions for Participants

Chapter 1

1.1) What was the boy's name?

a) Bud

b) Dan

c) Dibs

1.2) What were the names of the boy's teachers?

a) Miss Jane and Hudda

b) Miss Smith and Helena

c) Miss Jones and Hanna

Chapter 2

2.1) Where did the Psychologist take the boy?

a) Outside

b) The Principal's office

c) The Playroom

2.2) Did the boy go out for morning-tea/recess?

Y/N

Chapter 3

3.1) How much an hour did the psychologist charge an hour?

a) $50 (US)

b) $100 (US)

c) Nothing

Chapter 4

4.1) How long did the Psychologist have to wait for the boy's mother to return the signed consent statement?

a) A few days

b) A few weeks

c) Two months

Appendix A: Reading Comprehension Test (A-4)

Chapter 4...

4.2) Did the boy have his boots taken off in the playroom?

Y/N

4.3) Did the Psychologist think the boy was mentally retarded?

Y/N

4.4) Who picked the boy up from the session with the Psychologist?

a) Maid

b) Father

c) Mother

Chapter 5

5.1) What was in the playroom's sandpit?

a) Toy soldiers

b) Trucks

c) Bucket and spade

5.2) What did the boy give to the Psychologist?

a) A crayon

b) A painting

c) A handful of sand

5.3) How did the boy meet the person picking him up from the session?

a) Without a fuss

b) Kicking and screaming

c) Crying

Appendix B: Raw Data

Case	GROUP	GRP_NO	R1_FZ	R1_CZ	R1_PZ	R2_FZ	R2_CZ	R2_PZ	EPQ	CDQ	CDQ_GP	SOGS	N_OF_QS	QS_RIGHT	% Correct
1	R	1	-4.393	-3.536	-3.137	-9.569	-5.913	-4.961	18	52	1	0	4	4	100
2	N	2	-2.551	-1.226	-1.351	-5.244	-3.558	0.084	20	83	2	0	5	4	80
3	I	3	2.07	1.842	1.192	-2.534	-3.402	-1.253	8	100	2	0	4	4	100
4	N	2	0.437	1.029	0.395	-2.08	1.82	3.456	20	92	2	1	4	4	100
5	I	3	-4.964	-3.515	-3.214	-10.94	-10.993	-8.918	5	69	2	0	7	7	100
6	R	1	-5.648	-5.583	-3.877	-4.371	-4.561	-3.088	19	55	1	1	9	9	100
7	N	2	-2.397	-2	-0.952	-1.463	-1.028	-0.467	18	92	2	1	5	5	100
8	N	2	0.067	0.349	0.716	-4.666	-3.052	-1.645	20	84	2	0	3	3	100
9	R	1	1.142	2.315	3.143	-3.924	-0.879	1.655	19	61	1	0	12	10	83.33
10	R	1	-2.189	-2.651	-1.852	-4.038	-2.423	-1.187	20	60	1	0	12	8	66.67
11	N	2	0.124	0.51	-0.358	-2.381	-2.967	-2.703	19	85	2	1	3	3	100
12	I	3	-0.137	-0.669	-0.683	-6.417	-5.753	-2.54	8	91	2	0	4	4	100
13	R	1	-2.443	-2.834	-2.14	-0.782	-0.44	1.109	17	58	1	0	3	3	100
14	N	2	-1.668	-1.452	-1.703	-3.009	-3.188	-3.451	20	89	2	0	6	6	100
15	I	3	1.431	1.34	0.819	-2.726	-2.046	-1.619	4	74	2	0	4	4	100
16	N	2	-0.319	0.102	-0.321	-2.543	-3.433	-3.683	17	108	2	0	4	4	100
17	R	1	-1.879	-2.603	-3.038	-3.344	-3.246	-2.739	18	58	1	1	5	5	100
18	I	3	1.268	0.063	-1.25	-2.283	-4.877	-5.663	3	84	2	0	12	11	91.67
19	N	2	-1.531	-0.039	-0.304	-2.746	-2.249	-1.755	20	106	2	0	9	7	77.78
20	R	1	-1.106	0.031	0.11	3.022	2.766	-0.758	20	60	1	0	3	3	100
21	I	3	0.188	0.838	1.253	-1.119	-0.014	1.462	4	74	2	0	12	12	100
22	R	1	0.532	-0.009	0.442	-2.215	-2.438	-1.157	21	62	1	0	8	7	87.5
23	R	1	-0.188	-0.91	-6.581	-4.681	-5.265	-4.424	19	62	1	0	8	8	100
24	I	3	-1.154	0.05	0.85	-4.08	-5.187	-4.483	6	76	2	0	5	5	100
25	R	1	-1.181	-1.964	-0.929	-9.25	-9.63	-0.584	19	62	1	0	10	10	100
26	N	2	-0.964	-0.681	0.785	-5.666	-3.442	0.485	20	84	2	0	5	5	100
27	N	2	-1.739	-0.655	-6.504	-4.238	-2.858	-2.427	18	82	2	0	2	2	100
28	I	3	-0.763	-1.212	0.629	-2.524	-2.992	-3.606	7	71	2	0	8	8	100
29	I	3	-1.809	-1.526	-1.177	-3.724	-4.335	-3.977	9	41	1	0	8	8	100
30	I	3	-1.365	-2.212	4.736	-1.43	-0.31	-0.356	10	58	1	1	12	9	75

P3_R1_FZ	P3_R1_CZ	P3_R1_PZ	P3_R2_FZ	P3_R2_CZ	P3_R2_PZ	P2_R1_FZ	P2_R1_CZ	P2_R1_PZ	P2_R2_FZ	P2_R2_CZ	P2_R2_PZ
-1.688	-0.368	1.338	0.108	1.978	4.7	2.267	2.861	1.276	7.075	8.904	2.254
-0.912	1.366	2.624	2.391	0.631	5.035	-3.107	0.407	2.562	1.673	12.982	16.819
-0.015	0.029	0.486	2.493	2.551	6.338	3.071	3.735	1.531	5.241	7.568	5.742
-1.643	-0.526	0.85	-1.552	-2.039	4.275	1.503	3.821	3.731	0.934	10.446	4.609
0.51	-0.053	-0.431	0.58	-1.911	0.952	1.306	3.87	1.304	3.537	11.802	6.46
-1.697	-0.866	-0.03	4.082	3.251	4.238	-0.439	0.952	0.451	3.692	7.735	1.751
-2.58	-2.877	-1.615	3.478	1.482	0.436	-0.172	1.218	0.737	4.243	10.514	6.42
0.381	0.167	1.019	1.01	1.72	5.628	3.05	5.581	4.466	2.405	7.71	6.773
-1.884	-0.205	0.666	-0.575	2.49	5.268	1.373	3.765	4.297	0.628	6.797	5.157
0.042	-0.868	0.025	8.578	8.566	10.155	0.362	1.682	-0.197	-0.577	10.695	2.278
1.082	1.734	0.294	1.857	0.016	1.313	-2.326	0.494	-1.069	-0.578	5.098	-1.416
1.603	1.827	1.876	4.67	6.536	9.684	2.726	2.714	1.077	8.76	13.638	8.918
-1.131	-2.208	-1.604	2.643	2.884	6.304	1.005	1.326	-0.209	5.312	8.087	4.856
-2.918	-2.223	-2.17	-0.231	-0.45	2.156	-4.075	-2.618	-1.956	-3.087	-0.563	-2.114
1.918	1.41	1.841	-0.784	1.181	4.569	3.431	4.975	3.154	5.194	12.904	9.333
-0.351	0.962	2.84	2.941	0.411	5.262	1.052	3.683	3.289	3.582	6.973	3.923
-2.287	-1.886	-1.623	1.354	1.206	2.979	-2.004	-0.421	-0.962	-2.387	3.507	1.782
-0.768	-1.788	-2.025	0.847	-0.014	1.248	2.358	2.441	0.823	-1.077	6.446	2.416
-3.888	-2.21	-2.233	-0.083	-3.749	-0.39	-0.471	2.906	1.679	3.884	11.139	5.164
4.922	3.987	2.759	8.241	6.048	6.678	3.952	5.724	4.694	9.84	14.525	9.621
-2.888	-2.159	-1.06	-3.246	-2.374	0.896	0.213	2.442	1.517	2.421	12.704	8.373
-2.647	-3.785	-2.668	-1.189	-1.841	-1.167	0.664	0.446	0.475	6.199	8.967	6.22
-1.488	-0.709	-2.264	-1.147	0.153	5.254	-0.055	0.072	-6.175	-1.005	2.453	1.554
-1.689	-1.07	0.469	1.206	0.027	0.839	-2.158	-0.844	0.355	-2.131	-0.289	0.084
-0.908	-0.785	-3.458	7.415	5.811	23.873	-1.296	1.585	1.347	6.095	10.672	13.879
1.729	3.741	4.462	1.364	3.121	5.646	4.013	6.516	5.952	4.255	16.008	12.209
2.468	1.914	4.291	5.417	3.035	-5.037	1.977	4.449	-2.19	4.194	10.841	2.792
0.557	-1.088	0.975	0.786	-1.879	-3.067	1.654	2.692	5.172	2.651	8.306	5.995
-2.551	-3.299	-2.41	-0.343	-3.786	-1.413	-1.061	-0.514	-0.843	1.323	1.588	0.225
1.61	1.053	12.174	0.287	-0.492	9.7	1.103	0.797	9.765	0.899	3.768	3.655

1) MMN Analysis

a) Three-way ANOVA

STATISTICA GENERAL ANOVA — summary of all effects; design: 1-GRP_NO, 2-Tone, 3-Site

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
1	2	8.8200	27	19.97893	.44146	.6476532
2	1	183.6362	27	5.65912	32.44960	.0000047
3	2	15.7404	54	2.37179	6.63653	.0026480
12	2	21.5169	27	5.65912	3.80216	.0350873
13	4	1.1556	54	2.37179	.48724	.7450231
23	2	8.5820	54	1.63404	5.25200	.0082375
123	4	2.5025	54	1.63404	1.53149	.2061071

STATISTICA GENERAL ANOVA — **Means**

GRP_NO	R1_FZ	R1_CZ	R1_PZ	R2_FZ	R2_CZ	R2_PZ	Valid N
1	-1.73530	-1.77440	-1.78590	-3.91520	-3.20290	-1.61340	10
2	-1.05410	-.40630	-.95970	-3.40360	-2.39550	-1.21060	10
3	-.52350	-.50010	.31550	-3.77730	-3.99090	-3.09530	10
All Groups	-1.10430	-.89360	-.81003	-3.69870	-3.19643	-1.97310	30

STATISTICA GENERAL ANOVA — **Standard Deviations**

GRP_NO	R1_FZ	R1_CZ	R1_PZ	R2_FZ	R2_CZ	R2_PZ	Valid N
1	2.098063	2.212813	2.676544	3.687721	3.409236	2.181302	10
2	1.081878	.960673	2.116916	1.440977	1.659468	2.165519	10
3	2.026079	1.662984	2.107083	2.931449	3.143965	2.936655	10
All Groups	1.804936	1.751311	2.401010	2.753200	2.822803	2.507538	30

b) Means and Post-hoc Analysis of Tone's Main effect.

STATISTICA GENERAL ANOVA — **Means**

GRP_NO	Tone	Site	Depend. Var.1
••••	1	••••	-.93598
••••	2	••••	-2.95608

STATISTICA GENERAL ANOVA — Newman-Keuls test; Var.1 — Probabilities for Post-hoc Tests — MAIN EFFECT: Tone

GRP_NO	Tone	Site		{1} -.935978	{2} -2.95608
••••	1	••••	{1}		.0001470
••••	2	••••	{2}	.0001470	

c) Means and Post-hoc Analysis of Site's Main effect.

STATISTICA GENERAL ANOVA — **Means**

GRP_NO	Tone	Site	Depend. Var.1
••••	••••	1	-2.40150
••••	••••	2	-2.04502
••••	••••	3	-1.39157

STATISTICA GENERAL ANOVA — Newman-Keuls test; Var.1
Probabilities for Post-hoc Tests
MAIN EFFECT: Site

GRP_NO	Tone	Site		{1} -2.40150	{2} -2.04502	{3} -1.39157
••••	••••	1	{1}		.2103873	.0021137
••••	••••	2	{2}	.2103873		.0240232
••••	••••	3	{3}	.0021137	.0240232	

d) Means and Post-hoc Analysis of the Interaction Between Group and Tone.

STATISTICA GENERAL ANOVA — **Means**

GRP_NO	Tone	Site	Depend. Var.1
1	1	••••	-1.76520
1	2	••••	-2.91050
2	1	••••	-.80670
2	2	••••	-2.33657
3	1	••••	-.23603
3	2	••••	-3.62117

STATISTICA GENERAL ANOVA — Newman-Keuls test; Var.1
Probabilities for Post-hoc Tests
INTERACTION: 1 x 2

GRP_NO	Tone	Site		{1} -1.76520	{2} -2.91050	{3} -.806700	{4} -2.33657	{5} -.236033	{6} -3.62117
1	1	••••	{1}		.1685182	.1304244	.3606403	.0490146	.0263972
1	2	••••	{2}	.1685182		.0101423	.3585213	.0016096	.2575176
2	1	••••	{3}	.1304244	.0101423		.0488949	.3612195	.0009372
2	2	••••	{4}	.3606403	.3585213	.0488949		.0102739	.1106138
3	1	••••	{5}	.0490146	.0016096	.3612195	. 0102739		.0002294
3	2	••••	{6}	.0263972	.2575176	.0009372	.1106138	.0002294	

e) Means and Post-hoc Analysis of the Interaction Between Tone and Site

STATISTICA GENERAL ANOVA — **Means**

GRP_NO	Tone	Site	Depend. Var.1
••••	1	1	-1.10430
••••	1	2	-.89360
••••	1	3	-.81003
••••	2	1	-3.69870
••••	2	2	-3.19643
••••	2	3	-1.97310

STATISTICA GENERAL ANOVA — Newman-Keuls test; Var.1
Probabilities for Post-hoc Tests
INTERACTION: 2 x 3

GRP_NO	Tone	Site		{1} -1.10430	{2} -.893600	{3} -.810033	{4} -3.69870	{5} -3.19643	{6} -1.97310
••••	1	1	{1}		.5260535	.6479836	.0001613	.0001206	.0111515
••••	1	2	{2}	.5260535		.8011967	.0001324	.0001613	.0053421
••••	1	3	{3}	.6479836	.8011967		.0001380	.0001324	.0048199
••••	2	1	{4}	.0001613	.0001324	.0001380		.1340091	.0001269
••••	2	2	{5}	.0001206	.0001613	.0001324	.1340091		.0006097
••••	2	3	{6}	.0111515	.0053421	.0048199	.0001269	.0006097	

2) P3 Analysis

a) Two-way ANOVA with High Tones and Associated Means and Standard Deviations

STATISTICA GENERAL ANOVA — summary of all effects; design: 1-GRP_NO, 2-Site

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
1	2	86.23048	27	26.68501	3.23142	.0551840
2	2	71.65705	54	6.97897	10.26757	.0001663
12	4	6.06799	54	6.97897	.86947	.4882949

STATISTICA GENERAL ANOVA — **Means**

GRP_NO	Site	Depend. Var.1
1	1	2.951050
1	2	3.054510
1	3	6.828150
2	1	1.659440
2	2	.417760
2	3	2.432490
3	1	.649530
3	2	-.016140
3	3	2.974670

STATISTICA GENERAL MANOVA — **Standard Deviations**

GRP_NO	P3_R2_FZ	P3_R2_CZ	P3_R2_PZ	Valid N
1	3.915222	3.060260	6.639885	10
2	2.029731	2.143296	3.460804	10
3	2.062359	2.944239	4.419734	10
All Groups	2.876397	2.987786	5.236731	30

b) Means and Post-hoc Analysis of Group's Trend Towards Significance.

STATISTICA GENERAL ANOVA — **Means**

GRP_NO	Site	Depend. Var.1
1	••••	4.277904
2	••••	1.503230
3	••••	1.202687

STATISTICA GENERAL ANOVA — Newman-Keuls test; Var.1 — Probabilities for Post-hoc Tests — MAIN EFFECT: GRP_NO

GRP_NO	Site		{1} 4.277904	{2} 1.503230	{3} 1.202687
1	••••	{1}		.0472391	.0721895
2	••••	{2}	.0472391		.8235468
3	••••	{3}	.0721895	.8235468	

c) Means and Post-hoc Analysis of Site's Main Effect.

STATISTICA GENERAL ANOVA	**Means**	
GRP_NO	Site	Depend. Var.1
••••	1	1.753340
••••	2	1.152043
••••	3	4.078437

STATISTICA GENERAL ANOVA — Newman-Keuls test; Var.1
Probabilities for Post-hoc Tests
MAIN EFFECT: Site

GRP_NO	Site		{1} 1.753340	{2} 1.152043	{3} 4.078437
••••	1	{1}		.3820938	.0013605
••••	2	{2}	.3820938		.0003237
••••	3	{3}	.0013605	.0003237	

3) CDQ Analysis

a) One-way ANOVA with CDQ Scores.

STATISTICA GENERAL ANOVA — summary of all effects; design: 1-GRP_NO

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
	2	2483.633	27	123.8556	20.05266	.0000046

b) Means, Standard Deviations, and Post-hoc Analysis of Group's Main Effect.

STATISTICA GENERAL ANOVA	**Means**
GRP_NO	CDQ
1	59.00000
2	90.50000
3	73.80000

STATISTICA GENERAL ANOVA	**Standard Deviations**	
GRP_NO	CDQ	Valid N
1	3.33333	10
2	9.40744	10
3	16.49108	10
All Groups	16.92923	30

STATISTICA GENERAL ANOVA — Newman-Keuls test; CDQ
Probabilities for Post-hoc Tests
MAIN EFFECT: GRP_NO

GRP_NO		{1} 59.00000	{2} 90.50000	{3} 73.80000
1	{1}		.0001284	.0062816
2	{2}	.0001284		.0025079
3	{3}	.0062816	.0025079	

4) SOG Analysis

a) One-way ANOVA with SOG Scores.

STATISTICA GENERAL ANOVA — summary of all effects; design: 1-GRP_NO

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
1	2	.1000000	27	.1703704	.5869565	.5629554

b) SOG Means and Standard Deviations.

STATISTICA GENERAL ANOVA — **Means**

GRP_NO	SOGS	Valid N
1	.2000000	10
2	.3000000	10
3	.1000000	10
All Groups	.2000000	30

STATISTICA GENERAL ANOVA — **Standard Deviations**

GRP_NO	SOGS	Valid N
1	.4216370	10
2	.4830459	10
3	.3162278	10
All Groups	.4068381	30

5) Analysis of Comprehension Questionnaires

a) One-way ANOVA with Number of Comprehension Questions Attempted.

STATISTICA GENERAL ANOVA — summary of all effects; design: 1-GRP_NO

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
1	2	28.13333	27	9.155556	3.072815	.0627561

b) Means and Standard Deviations.

STATISTICA GENERAL ANOVA — **Means**

GRP_NO	N_OF_QS
1	7.400000
2	4.600000
3	7.600000

STATISTICA GENERAL ANOVA — **Standard Deviations**

GRP_NO	N_OF_QS	Valid N
1	3.470511	10
2	1.955050	10
3	3.405877	10
All Groups	3.234868	30

STATISTICA		Newman-Keuls test; N_OF_QS		
GENERAL		Probabilities for Post-hoc Tests		
ANOVA		MAIN EFFECT: GRP_NO		
		{1}	{2}	{3}
GRP_NO		7.400000	4.600000	7.600000
1	{1}		.0483443	.8837000
2	{2}	.0483443		.0864084
3	{3}	.8837000	.0864084	

c) One-way ANOVA with the Percentage of Correct Comprehension Questions.

STATISTICA GENERAL ANOVA — summary of all effects; design: 1-GRP_NO

Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
1	2	22.35332	27	90.85846	.2460236	.7836375

d) Means and Standard Deviations of Group Percentages.

STATISTICA GENERAL ANOVA — **Means**

GRP_NO	%
1	93.75000
2	95.77800
3	96.66700

STATISTICA GENERAL ANOVA — **Standard Deviations**

GRP_NO	%	Valid N
1	11.32550	10
2	8.91613	10
3	8.05054	10
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All Groups	9.28084	30